INDIRECT REFERENCE
IN GERMAN MATHEMATICAL DISCOURSE

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Declaration

I declare that this thesis has been composed by myself and that the research reported therein has been conducted by myself unless otherwise indicated.

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ABSTRACT

This thesis investigates indirect reference in German mathematical discourse and the principles of its interpretation. It is specifically concerned with the author's indirect reference to himself and to the immediate and general audience.

The need to include pragmatics in the analysis of scientific discourse is expressed in the thesis and the rhetoric of science is discussed from the pragmatic perspective. The restricted context of scientific communication and the pragmatic characteristics of the latter are described.

The predicate frame model, based on the principle of verb centrality and employing the notion of prototypical participants, is introduced. The indirectly referring expressions are interpreted in terms of the model. A restricted set of prototypical participants is analysed and further related to the concept of the context-specific discourse roles. It is argued that in the restricted context of mathematical discourse, indirectly referring expressions, traditionally labelled as impersonal or indefinite-personal, are assigned definite-personal interpretations.

Further, the reference-supporting and reference-switching function of deictic elements is discussed in terms of the predicate frame model and discourse roles. Particular emphasis is put on reference switching in the case of indefinite and generalised pronouns. The hierarchical structure of the system of indirect reference is described and commented on.

Finally, the possible applications of the model are presented and some lines of further research are suggested.

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CHAPTER 1

SYNTAX AND SEMANTICS OF IMPERSONAL CONSTRUCTIONS

1.1 Introduction

1.1.1 Purpose and Scope of the Research

The aim of the research presented in this thesis is to analyse the linguistic means available in German for expressing self-reference in an indirect way, i.e. not with the 1st Person Singular sentences. The main interest is focused on the mutual dependency between the syntax of a clause and its semantic interpretation when some participants in the event described by the predicate are not expressed.

For a variety of reasons the speaker may leave the acting participant in an event (including himself) not specified overtly. The acting person may be unknown to the speaker, known but irrelevant for the purpose of communication, not important for some other reason, or known but the speaker prefers not to reveal his or her identity. The latter may result from e.g. tact or politeness; it may also result from a desire to deceive the hearer or to avoid committing oneself or others to something.

Focusing on the motivation for omitting explicit reference to oneself (i.e. self-reference) allows us to limit the possible reasons. The research presented here has been carried out on texts from the domain of scientific (mathematical) communication, where the phenomenon of apparently impersonal narration is particularly common. Moreover, the justification for this type of self-presentation in science seems to be more uniform than in everyday communication. By analysing data from written and spoken German mathematical texts we examine ways of *impersonal*, i.e. indirect, self-reference in science and describe them using a model of relations between syntactic, semantic and pragmatic components of discourse (described in detail in Chapter 3). In this thesis we argue that for predicates related to prototypically human activities, referents can be correctly inferred even if only indirect means of referring are used.

In this chapter we look at some syntactic means available in language that permit the acting participant to be demoted or removed from the clause structure. The most common means of demoting the agent-like argument, available in Indo-European languages, are:

1. impersonal constructions, including:
   a. personal and impersonal passives;
   b. pseudo-reflexive expressions with originally non-reflexive verbs and objects promoted to the subject position;
   c. subjectless (e.g. infinitival) constructions;

2. nominalisation, i.e. replacing constructions with action verbs and prototypically human subjects by expressions with a copula verb and an adjective or noun as a predicative.

The impersonal self-presentation may also be achieved by means other than those of syntax, for example by pronoun shift. We describe this phenomenon in Chapter 4. There, we examine also the changed linguistic representation of the communicative situation, i.e. representation from which the direct reference to the speaker has been removed. In this context we analyse shift in form and function of other deictic elements.

In Chapter 2 we review the literature on linguistic research related to languages for specific purposes and indicate current tendencies in that field. We further discuss the necessity of including a pragmatic component in analysis of language phenomena in scientific communication.

In Chapter 3 we present the predicate frame model. This model is used in the thesis to describe the mechanism of semantic interpretation when the syntactic structure does not fully specify the arguments of the predicate.

In Chapter 4 we discuss the methods employed to analyse the linguistic data. The analysis of the data from the written and spoken German mathematical texts is presented and commented on.

Chapter 5 summarises the research carried out on the impersonal presentation of self and indicates the most striking examples of the functional dependency between different levels of language analysis. In this last chapter we also point out some other areas of linguistics where application of the predicate frame model might be fruitful.

1.1.2 Terminology

In this subsection we introduce the terminology that will be used throughout this and the following chapters.

Lack of explicit reference to the participants involved in an event results in syntactic constructions which, in the Indo-European linguistic tradition, were labelled as *impersonal*. Cross-linguistic studies show that most languages tend to represent events and actions in an 'egocentric', 'speaker oriented' way, i.e. to give *human agents* a special syntactic status (cf. e.g. Benveniste [1948], [1966], Slobin [1982]).

In Indo-European languages, expressions used to refer to human agents typically coincide with the grammatical subjects of action verbs. And since Subject-Verb-Object is the neutral word order in most of these languages, the grammatical subject further coincides with the *topic* (we adopt here the definition of topic as the first constituent in the clause, often corresponding to the 'given' information, i.e. to 'Datum' - c.f. Halliday [1967], Beneš [1967]). We may therefore assume that an unmarked, neutral syntactic construction, used to describe an action performed by the speaker, would have a self-referring expression as a subject (in topical position) of an action verb (we leave the discussion of semantic verb types till Chaper 4 where this question is analysed for real data). In German, the unmarked choice would be a fully specified active clause. We shall investigate how the argument of the verb, co-referential with the subject of an active clause, may be demoted to another position in the clause or simply omitted, and how this demotion affects the semantic interpretation of that clause.

In the research on *impersonal constructions*, confusion is caused by an inconsistent use of terminology. Since any description or analysis of this phenomenon naturally involves taking account of the syntactic as well as semantic level of representation, notions such as *subject/agent* and *object/patient* are used indiscriminately. To keep these two different levels of linguistic analysis clearly separated, we first define the notions used for their description.

For the semantic analysis we adopt the predicate-argument approach and use the notion of *arguments* or *participants*. For monovalent verbs, i.e. those associated with one participant only, no further distinctions are

needed. The (semantic) selectional restrictions on the entity that can associate with the predicate depend on the semantics of the verb. We discuss this problem in more detail in Chapter 3; here we merely introduce the notion. For polyvalent verbs, a further distinction between 1st, 2nd and 3rd participant is necessary, the indices corresponding to the intrinsic, language specific ordering of the arguments associated with the verb. In Indo-European languages, the 1st argument is commonly the one denoting the instigator of an action for action verbs, or the recipient of the action (in most cases an action of transmitting something) for verbs of 'getting', 'receiving' etc., cf. Kirsner [1976]. It seems quite natural that for actions involving humans in two different roles, languages have verbs that can present both as 1st participants. This is the case for the reversible actions of buying and selling, teaching and learning, giving and receiving etc. For our purposes, it is the 1st-argument-position that will be of most interest. The intrinsic ordering of the remaining participants is language specific and can be established through syntactic tests (e.g. passivisation of the second object). We return to this question in Subsection 3.2.3.

In this thesis we shall concentrate on syntactic changes caused by removing the 1st participant of the verb from the clause perspective, which may correspond to the promotion of other participants to the syntactic subject position. This observation, however, cannot be generalised since there is no obligatory equivalence between the 1st participant and the grammatical subject of an unmarked sentence. Before we move on to this question we shall define the notion of subject as it will be used throughout this thesis.

The term *subject*, as it is employed here, belongs to the level of syntactic description and as such must be defined in purely syntactic or syntactic and morphological terms. Traditionally, however, subject was given a broader definition. It was defined as the nominal constituent of a sentence (in the Nominative case), where the sentence was seen as built up of two major constituents - the subject and the predicate. The subject denoted a concrete or abstract thing about which the predication was made, and it also determined the morphological shape of the predicate. The concepts of subject and predicate originally come from Aristotelean logic, where they have been defined in a multidimensional way, i.e. comprising aspects of thought, speech situation and existence of objects in the real world. The confusion caused by combining

formal, ontological and referential aspects into one notion may be illustrated by specifying various types of subjects in theories of grammar. We find the following terminology: overt and implicit subjects, formal or empty subjects of impersonal verbs, logical subjects that do not necessarily correspond to grammatical subjects etc. Subject understood as 'what the sentence is about' (German *Satzgegenstand*) may also be identified with the notion of *theme*, thus bringing the communicative aspect into consideration.

The complex nature of the linguistic concept of subject may be seen as resulting from the way the syntactic relations within the sentence developed, since that process must have involved both semantic and pragmatic factors. Analysing syntactic functions and changes in word order in some languages, von Seefranz-Montag [1983] points out the importance of the relative frequency with which verb arguments were topicalised and its function in the transition from the purely semantic to semantic-syntactic role of cases in Proto-Indo-European (cf. also Li (ed.) [1976]).

The necessity of separating the formal characteristics of grammatical subjects from other aspects of their description has been advocated by many authors and was carried out e.g. by Fries [1952]. Fries defined sentence constituents in grammatical terms without relating them "to the actual facts of a situation in the real world" (p. 175). Subject was for him merely the technical name for the Class 1 word (i.e. roughly speaking a nominal phrase) that is structurally bound with a Class 2 word (i.e. verb). The clear separation of structural characteristics was, however, for Fries a goal in itself and he did not relate the formal syntactic representation to other levels of language description.

A consistent attempt to describe the relations between notions from three levels of representation has been carried out by Hagège [1984] who distinguishes between three points of view with respect to 'subject' - the morpho-syntactic, the semantic-referential and the communicative-hierarchical (French "énonciative-hiérarchique"). Stressing what has already been pointed out in generative grammar (cf. Chomsky [1965] p. 96) - that *subject* and *predicate* are relative notions (i.e. that we may merely talk about *subjects of* in relation to a certain predication) - he further notes that the analysis of the complex notion of *subject* must comprise all three aspects but not confuse them. Thus,

the morpho-syntactic definition as an ultimate goal of the subject description is rejected. Hagège points out that:

> "le point de vue morphosyntaxique n'est pas le seul à retenir, qu'il est relié aux deux autres, et que, comme l'indiquent les flèches, le terme autre que le prédicat correspond le plus souvent à un patient ou à un agent du point de vue 2 (i.e. semantic-referential - M.S.), et à un thème du point de vue 3 (communicative-hierarchical - M.S.). Ces deux notions sont associées (quand elles ne sont pas confondues avec elle) à la notion de sujet." (pp.352-353)

Following Hagège [1984], we limit *subject* to the morpho-syntactic level of description, defining it as that nominal phrase which is bound to the predicate by a language specific structural and mutual relationship. We discuss some details of this relationship in Section 1.2 in this chapter and in Chapters 3 and 4. The current literature on the questions related to *subjects*, *topics* and *participant roles* is very rich. A summary of the problems in that field is presented by e.g. Li (ed.) [1976], especially in papers by Keenan, Li & Thompson and Givon included in the selection. An interesting presentation of typological research on the subject is given by Handwerker [1984].

1.2 Basic Properties and Functions of Impersonal Constructions

1.2.1 Introduction

In the rest of this chapter, we comment on the properties of syntactic constructions considered as impersonal, pointing out their common features and indicating how they have been analysed in past linguistic research. We begin by examining the notion *impersonal* and its relevance to impersonal self-reference in scientific texts. In this section we review the two syntactic approaches to impersonal constructions - one that sees their functions as *object promotion*, the other as *subject demotion*. The following section describes the traditionally recognized types of impersonal constructions, with examples from different languages.

1.2.2 Object Promotion

Constructions such as passives or pseudo-reflexives may be considered as means of promoting the object arguments of polyvalent verbs to the syntactically and communicatively more prominent subject/topic position.

The view that the change in subject position is the major characteristic of impersonal constructions owes much to the emphasis put on the logical distinction between subject and predicate in traditional syntactic analysis. Consequently, the possibility of promoting direct objects to the subject position, was treated as the major function of passive or reflexive constructions. This corresponds to the tradition widespread in linguistics, according to which active is the norm while passive and passive-like expressions are seen as paraphrases or transformations of the active that do not contribute anything new to the propositional meaning. Wackernagel ([1920] p. 135), referring to previous studies on the Indo-European passive-forms (in particular to the research by von der Gabelenz [1861]), is a typical representative of this approach in German linguistics:

> "Mit Recht hat man das Passiv als einen Luxus der Sprache bezeichnet, weil der passivische Satz nichts anderes darstellt als die Umkehr des normalen aktivischen Satzes".

Von der Gabelenz (ibid.) considered the passive merely an additional linguistic form expressing the same content as the active. However, he

believed that this was worthwhile investigating, "wie der menschliche Geist ... darauf geführt sein mag, diese Form der Darstellung zu wählen und ihr in der Sprachbildung einen Einfluß einzuräumen" (p. 455). (We must note that he did not consider sentences with transitive verbs, but without agent expressions, as passives.) Brugmann & Delbrück [1926] pointed out that the major motive of the development of the passive in the Indo-European languages was "das Bedürfnis dem Objekt eines Vorgangs eine zentrale Stelle im Satz anzuweisen und es damit psychologisch über die Agensstellung zu erheben" (p. 701). In German, the passive, without any doubt, developed later than the active (cf. Tschirch [1969] pp.30n). This secondary character of the passive in German is demonstrated by morphological studies that clearly show its irregular and defective character. The big variety of 'passive-like' constructions gave rise to linguistic studies on the common 'meaning' of different variants of German passive and its equivalents (cf. Glinz [1962], Erben [1980], Pape-Müller [1980] - on the passive in general cf. Stein [1979] and Siewierska [1984]). However, the assumption that passive and the impersonal passive-paraphrases are just means for promoting the object constituent to the topical, i.e. syntactically and communicatively prominent position, fails to provide a common coherent explanation for this linguistic phenomenon. One reason for this failure is obviously the fact that some of those constructions do not allow for object promotion, but preserve the same *functional sentence perspective*, i.e. the same topic-comment structure or thematic organisation. (We shall use the notion of the functional sentence perspective, introduced in the Prague School by Mathesius and further developed in the Neo-Prague-School by Beneš [1967] and Firbas [1964]. This concept is more suitable for the description of German than the purely positional notion of *topic*.) The subjectless impersonal constructions, on the other hand, simply lack grammatical subjects.

The first case may be illustrated with the German constructions with the indefinite-personal pronoun *man*, commonly considered as a passive paraphrase, where there is neither reverse ordering nor reduction of verb arguments. The two examples in (1):

(1) a. Die Leute schreiben die meisten Briefe zu Weihnachten
'people write most letters at Christmas'
b. Man schreibt die meisten Briefe zu Weihnachten
'one writes most letters at Christmas'

have the same number of expressed verb arguments and these arguments have the same linear order. The 'corresponding' passive in (2):

(2) a. Die meisten Briefe werden zu Weihnachten geschrieben
'most letters are written at Christmas'
b. Die meisten Briefe werden (**von man/?von den Leuten*)
zu Weihnachten geschrieben
'most letters are written (*by one/?by people) at Christmas'

has the number of overtly expressed arguments reduced by one. The argument corresponding to the subject of (1a and b), i.e. the 1st participant of the verb *schreiben* has been omitted, being replaced by the former Accusative object.

A clear example of the second type of construction that fails to promote objects to the subject position, are impersonal passives of intransitive verbs in German. Since there are no other participants involved, the subject position remains empty. Alternatively, if no particular circumstances of the event are specified and topicalised, it is filled in by a dummy *es*. The 'object promotion' approach cannot explain the fact that not all intransitive verbs allow the impersonal passive, which is possible only for events where human activities are described (cf. Brinkmann [1971] pp. 204n). Thus, to determine whether passive is allowed for a particular verb, it is necessary to refer to the semantics of the subject of the active clause.

1.2.3 **Subject Demotion**

It is appealing to consider object promotion in the passive as a process necessarily involving simultaneous subject demotion. In fact in some languages (viz. English) passive involves the simultaneous promotion of an object up the hierarchy of syntactic relations and demotion of the subject down the hierarchy (including the possible subject deletion). Since the English passive involves both processes, it is legitimate to ask (cf. Comrie [1977]) whether in other languages these two phenomena exist independently, i.e. whether there are languages with passives involving only object promotion or only subject demotion.

There is no linguistic evidence for the existence of passives with object promotion only. A possible exception may be noted in North

Russian. A detailed analysis of North Russian passives is given by Timberlake [1976]. However, the examples quoted by Timberlake involve the Russian locative equivalent of the predicate *to have* and therefore the 'promotion only' interpretation would not be appealing. The author gives the two locative phrases a distinct interpretation, considering the one as a *possessor* and the other as *agent*.

Comrie [1977] refers to the constraint proposed in Relational Grammar (the so called Relation Annihilation Principle - for discussion cf. Johnson [1977]) and based on English, that there can be no rules of spontaneous demotion of the subject, since, in English, any subject demotion is a direct result of the promotion of the object. The sentence cannot have two subjects and therefore the old subject must be removed, i.e. deleted or demoted. Comrie concludes that, consequently, such demotion is not *spontaneous*, but he also points out that the evidence from English does not allow us to infer that there are no languages with a spontaneous demotion of the subject. In fact, there are several languages with impersonal passives having subject demotion or deletion but lacking object promotion. The examples given in Comrie [1977] include Spanish, Latin, German, Dutch, Polish, Welsh and Finnish impersonal passives. The impersonal passive of German monovalent verbs has been recently analysed from the functional point of view in Latzel [1984]. He considers the German *werden + Partizip II* constructions as means of *nominalisation* of the action expressed by the verb, i.e. presentation of the action as agent-independent (German "losgelöst vom Täter" - p.49). The agent, even if not expressed, is still "mitgesetzt", i.e. understood as being involved. Kirsner [1976] presents an analysis of Dutch 'impersonal passives', considering them as means of an 'absolute backgrounding' of agent-like participant. Kirsner points out that, although the 'high participant' (the one "which ranks comparatively high on a scale of relative contribution to the bringing about of the event named by the verb" p. 389) is not focussed, i.e. not foregrounded as grammatical subject, he is still involved in the event and seen as a contributor to the occurrence named by the verb. For English, the syntactic, semantic and pragmatically-referential constraints on the 'agentless passive' have been analysed by Weiner & Labov [1983], who investigate the conditions that determine speaker's choice of the agentless passive or generalised active (i.e. use of the generalised pronouns *they, you, we*). The distinction between different types of impersonal constructions is based on speaker's/hearer's

knowledge of the referent (± definite, ± specific) and on the distribution of the given/new information, i.e. on the pragmatic function assignment. Also for Chafe [1970], passive has simultaneously two functions: one is to allow the verb to occur without the 1st participant (agent or experiencer), the other is to change the order of the given/new information. This approach derives from the research carried out in the works of linguists from the Prague School, e.g. Firbas [1964] and from Halliday [1967].

The backgrounding of the 1st participant for some pragmatic reason and the syntactic reflexion of this backgrounding, i.e. the subject demotion or deletion seem to be a common characteristic of Indo-European passive and impersonal constructions. Thus, to provide an adequate interpretation of a given impersonal construction it is necessary to account for the pragmatic aspects of the discourse to which it belongs, and to consider the pragmatic choice as having a primary influence on the choice of syntactic structure.

This insight is now generally recognized and has become a basic assumption of some linguistic studies, especially in discourse analysis. It is, however, relatively new in the form-oriented linguistic research prevalent in British and American linguistics, although it has an unbroken tradition in basic language description. It has a longer tradition in Germanic linguistics and we close this section with some remarks on Indo-European passives by Weisgerber.

In his [1963] study, Weisgerber clearly indicates that the only consistent approach to this question would be to look for a key to the problem of passive "in der geistigen Rolle des Subjekts" (p. 247). He continues:

> "Wenn man nach etwas sucht, was allen aufgezeigten passivischen und passivähnlichen Verfahrensweisen in echter Opposition gemeinsam ist, so findet sich das in der A u s c h a l t u n g d e s a g i e r e n d e n T ä t e r - s u b j e k t s . Das gilt ebenso für die passivischen Formensysteme wie für die unpersönlichen Passivbildungen, wie für die reflexiven Verfahrensweisen, wie für das Einsetzen des Dativobjekts an die Subjektstelle über *bekommen*, wie für ein *gelangt zur Aufführung*, wie schließlich sinngemäß auch für ein unpersönliches *man*. Was allen gleicherweise zukommt, ist offenbar die sprachliche Fassung von Geschehnissen ohne herausgehobenen Urheber." (p.247).

And further:

> "Die nicht aktivischen Sprachmöglichkeiten, die sich in verschiedener Weise und in verschiedenem Umfang ausbilden, setzen nicht an der Lage des 'Behandelten' an, sondern an der Stellung des 'Handelnden'... . Aktiv-Passiv, das ist also hier verbale Forderung nach einem aufweisbaren 'Täter', dort Belassen (oder Zurückversetzen) des Agens, des 'tatsächlichen' Trägers, unter den anders geordneten Komponenten eines Geschehens, das man nicht auf einen dafür Verantwortlichen zurückführen will." (p.248)

Instead of the term 'passive', Weisgerber uses the notion "täterabgewandte Diathese", since this corresponds better to the abstract meaning of passive and passive-like constructions. He also notes that, because of the basic properties of Indo-European personal verbs, a fully agentless presentation is impossible. .

We come back to this question in Chapter 3, where we analyse the representation of semantic roles associated with personal predicates. The fundamental concept of agents being potentially inferrable from the inherent properties of these predicates is discussed there in more detail.

Most studies of impersonal constructions start with an analysis of their form (syntax) and, by means of syntactic analysis, arrive at a semantic interpretation. This research does not attempt to give a full description of impersonal constructions available in German. We begin by defining a specific pragmatic condition to be satisfied (i.e. non-direct self-reference of the speaker in scientific communication) and we analyse data looking for syntactic options that meet the requirements imposed by pragmatics (Chapter 2). In the following section we present some general types of impersonal expressions and analyse their syntax and semantics.

1.3 Illustration of the Influence of Language Type on the Syntax of Impersonal Constructions

1.3.1 Impersonal Verbs

In this subsection we discuss the common syntactic means of demoting the 1st participant of a verb from the clause perspective. We start by examining the notion *impersonal* and its applicability to constructions with demoted 1st participant.

The term *impersonal*, as not referring to any particular person, not influenced by personal feeling or having no existence as a person, was originally used in traditional grammar to refer to verbs which, due to their semantics, could not occur with personal subjects. Those verbs, the *impersonalia*, usually describe events or processes where natural forces are causally involved. Some examples are given in (3):

(3) a. It rains
b. Es regnet
c. Il pleut
d. Pluit

According to the syntactic requirements of a particular language, determined among other factors by the degree of inflectionality, these verbs may either occur with a 3rd Person Singular pronoun (English, German, French) or without any overt subject at all, but with the inflection of the 3rd Person Singular, as in Latin and in Slavic languages.

However, RAIN verbs, commonly treated as a standard example of impersonal verbs, exhibit different syntactic properties in Slavic languages cf. (4).

(4) a. Deszcz pada literally 'rain falls'
b. Dožd' idet literally 'rain goes'

In the Polish construction in (4a) and in the Russian (4b) we have a grammatical subject noun *deszcz/dožd'* ('rain') and the construction must be treated as syntactically 'personal'. In Polish, however, there exist two parallel constructions - one which is truly 'impersonal' (i.e. no subject is possible) and one which is 'personal', as illustrated in (4). They are put together in (5).

(5) a. Deszcz padał 'rain fell' personal
b. Padało 'it fell' impersonal
c. Pada 'it falls' personal/impersonal

The example in (5c), where the Present Tense is used, allows for both personal and impersonal interpretation since no Gender distinction is made. An identical construction for this verb is also used in Ukrainian. However, it is not possible for the Russian example in (4b):

(6) a. Dožd' šel 'rain went' personal
b.*Šlo *'it went' impersonal
c. Dožd' idet/*idet 'rain goes' personal/*'it goes' impersonal

where the subject noun cannot be omitted. On the other hand, an overt subject in (4a) or in the German example in (7b):

(7) a. Es regnet
'it rains'
b. Regen regnet auf das Dach
'the rain rains on the roof'

may be considered as pleonastic or redundant, since the verb may also occur without it (i.e. with the impersonal pronoun *es* in German or with impersonal verb inflection in Polish) and the meaning of the proposition remains unchanged. The communicative value of (5b,c) must still be inferred either from the non-linguistic context (that is from the knowledge about the weather outdoors) or from general knowledge of the world (i.e. typically rain, possibly snow in the winter, assuming European weather conditions). Both the impersonal (subjectless) and the personal (having an overt lexically specified subject) constructions of that type may co-occur with a wide range of adverbs of manner, time and place.

If verbs which, because of their semantics, naturally belong to the class of impresonalia (e.g. verbs describing weather phenomena), occur with lexically specified subjects, as in (7b) or in (8):

(8) a. Dann *schneiten* ihm immer neue Gäste ins Haus
'then new guests kept pouring into his house'
b. Vater hat mächtig wegen unseres Zuspätkommens *gedonnert*
'father flew into great rage because we came too late'

c. Schwefel regnete auf Sodom und Gommorha
'sulphur rained down on Sodom and Gommorha'

we recognize the metaphorical shift in meaning. A similar metaphorical shift takes place if nouns like *rain, snow, snowflakes* etc. occur not with their prototypical verbs (or semantically neutral verbs, e.g. verbs of location *to lie, to cover* etc.) but rather with verbs without any impersonal subject restrictions or with verbs typically associated with human or animate 1st participants. This is illustrated in (9):

(9) a. The snow blocked the road
b. Deszcz uszkodził nawierzchnię drogi
'rain damaged the surface of the road'
c. Die Schneeflocken tanzten in der Luft
'the snowflakes danced in the air' .

The *Duden Grammatik der deutschen Sprache* [1984] adds to that confusion with a comment:

> "Neuerdings scheint es bei den 'Geräuschmachern' in Theater, Fernsehen und Film auch nicht ungewöhnlich zu sein, daß man Redewendungen wie *Ich donnere/regne* usw. gebraucht." (p. 556)

In this case, however, it would be more appealing to say that *ich donnere* and *es donnert* are not different uses of the same lexical item but rather that we have two different lexical entries in the lexicon for the form *donnern*.

Since for the analysis of scientific discourse we are interested in impersonal constructions rather than in semantically impersonal verbs of the type *to rain* or *to snow*, we concentrate here on the discussion of the semantic and syntactic status of the German impersonal pronoun *es* and its equivalents in other languages.

1.3.2 Impersonal Constructions with *es* and its Equivalents in Other Languages

The discussion of the syntactic status of *es* in impersonal constructions necessarily leads to an area of language description which the *Duden-Grammatik* [1984] refers to as "ein der umstrittensten Kapitel der Sprachwissenschaft" (p. 555).

There has been a controversy as to whether it is possible to assign *es* any semantic content. *Es* may be seen as an empty, dummy subject,

purely formal *Platzhalter* (to secure the 'verb-second' word order) etc. However, it has also been argued that *es* in German is an expression of an unknown force, "Ausdruck für das Wirken unpersönlicher, irrationeler oder mythischer Kräfte". The *Duden Grammatik* continues:

> "Aber auch wer mythologischen Deutungen gegenüber skeptisch ist, dürfte doch für nachstehende Wendungen (as e.g. *es regnet, es nieselt* etc. - M.S.) die Ansicht zulassen, daß mit dem 'es' eine nicht näher zu bestimmende Ursache des Geschehens angezeigt wird". (p. 555)

If we compare the communicatively equivalent constructions in different languages, even within the Indo-European family (cf. examples in (3) and (4)), it is apparent that languages may present those mysterious impersonal forces with different degrees of explicitness. While English, German or French use lexically meaningful, autosemantic verbs, combined with pronouns *it/es/il* respectively, to mark the impersonal character of the verb, Slavic languages often condense the lexical content in the noun which is then accompanied by a semantically neutral verb, expressing merely the kind of movement involved.

In the Polish (4a) we have a fixed construction with a restricted set of possible subject nouns: {*deszcz* ('rain'), *śnieg* ('snow'), *grad* ('hail')}. The situational context makes the choice of one of them highly predictable. As a consequence, the construction may be used without any subject noun and may become 'secondarily' impersonal. Note that in the Present Tense the morphological distinction between 'personal' and 'impersonal' use (reflected by the Masculine or Neuter Gender marking respectively) cannot be made - no subject NP is required because of the deictic character of the Present Tense impersonalia. This means that Slavic languages do not necessarily present the weather phenomena as results of 'unknown forces'; they may present the rain (snow etc.) as proper syntactic subjects, assigning them weak actor character.

Yet another way of viewing the weather phenomena may be found in e.g. Southeastern Pomo, an Indian language in North America. The equivalent of English *it's raining* is given in (10):

(10) scen scekit

where the meaning of the verbal stem /sce-/ may be represented as 'objects are distributed on a surface' (the features 'source' and 'motion' are not present) and /sce+n/ has the nominal interpretation

'rain' (-n is an absolutive suffix forming adjectives from certain verbs, such as those indicating quality, as well as states of action nouns) (cf. Moshinsky [1974] pp. 78 and 87).

A proper impersonal character is found in the Latin (3d), where the verb does not allow any noun to be a subject. Similar constructions are found in Slavic languages such as Polish, Ukrainian or Russian, cf. Polish examples in (11):

(11) a. Grzmi
'it thunders'
b. Świta
'it dawns'
c. Ściemnia się
'it is getting dark'
d. Błyska się
'it lightens'
e. Chmurzy się
'it is getting cloudy' .

In the examples above, no subject nouns are acceptable, possibly with the exception of (11c,e). One could think about the noun *niebo* ('sky') being the possible subject (omitted for the same reason as *deszcz* in (5c)), since the constructions in (12) may also occur:

(12) a. Niebo ściemnia się
'the sky is getting dark'
b. Niebo chmurzy się
'the sky is getting cloudy' .

This interpretation, however, fails, because in some contexts *niebo* cannot be assumed to be a proper, elliptically omitted subject. For instance (13), where two clauses are coordinated, would be marked as ungrammatical under the coreferential reading. Since it is a correct coordination, the coreferentiality of the implicit subject of the first clause and the explicit subject of the second clause (i.e. *niebo*) is not acceptable.

(13) Ściemniło się i niebo pokryło się gwiazdami
'it got dark' impersonal 'and the sky covered itself with stars' personal with a Neuter subject .

The analogous examples from Ukrainian are given in (14), quoted from the Ukrainian Grammar by Stechishin [1966]:

(14) a. Svitae
'it dawns'
b. Smerkae
'it is getting dark'
c. Nini xmarit'sja
'it is getting cloudy today' .

They are accompanied by a following comment: "In all the above examples, the English sentences have 'it' for their subjects. In no case does 'it' refer to any real subject, therefore it is known as a grammatical subject only. In Ukrainian the grammatical subject is not expressed" (p.241). In section 1.1.2, we commented on the inconsistent use of the notion of *subject* illustrated in the above passage.

What is surprising about Polish and equivalent Ukrainian constructions of the type illustrated in (11 c,d,e) and (14c) is the fact that they are reflexive. They have a reflexive pronoun *się* or a reflexive suffix *- sja*, but there is no constituent that could serve as its antecedent. Since the analysis of reflexivisation traditionally assumes the mutual dependency of two co-referential nouns within a syntactic construction this would suggest the existence of a subject in an impersonal construction.

The existence of any (whether grammatical or logical) subject in sentences labelled by traditional grammar as subjectless, is, however, counter-intuitive for a native speaker. Even if, historically, those constructions could have been associated with some kind of argument, this association path is now blocked and if we were to describe the predicate argument structure of the sentences in (11) or in (14), we would have a null argument predicate P(Ø) (on the subjectless construction in Polish compare Gołąb [1975] and Brajerski [1978]).

The apparently subjectless constructions in Slav languages pose yet another difficulty for the formal description and this is because of the possible WH-complement question as in (15):

(15) a. Dziś rano bardzo padało
'it was falling badly this morning' impersonal

b. Co padało?
'what was falling?' impersonal;
Deszcz czy śnieg?
'rain or snow?'
c. Deszcz/Padał deszcz/*Padało deszcz
'rain/rain was falling/*it was falling rain' impersonal .

That fact may be explained by the existence of two parallel constructions, as in (5a,b), one of which is 'personal' with a subject noun, the other one 'impersonal'. The verb *padać* ('to fall') in this construction is not contextually autonomous and that is why we should probably consider (5a) as a primary construction. Consequently, (4b) is only 'secondarily impersonal', i.e. built up in an analogous way to the other impersonal constructions. This impersonalisation is possible because of the fact that the verb *padać* allows only for a small set of nouns to appear in the subject position (we could call them perhaps 'cognate subjects'). The limited number of possible subjects makes the choice of subject highly predictable in most contexts. This, in turn, makes it possible to leave the subject unspecified, which could lead to the secondary impersonalisation of the already 'subjectless' construction. On the other hand, the parallel fully specified construction, and the choice of the 1st argument from the set of {rain, snow, hail} enables the speaker to ask the question *What is falling?*. The question whether the WH-construction is impersonal or personal remains open. Apparently the verb shows impersonal inflection, as in (15a). It could, however, be argued, that it is simply the neuter WH-word *co* ('what') that requires the personal neuter inflection on the verb, and this argument is appealing.

Looking at the Polish examples, the question arises, at what level of representation does the subject exist, if at all? We must assume that it is not (or does not have to be) the level of syntactic description, to account for yet another type of subjectless reflexive construction as in the Polish example in (16):

(16) Litowano się nad nim
'there was a feeling of mercy for him'
impersonal-reflexive .

Here, the morphological form of the predicate (historically Nominative Singular of the passive past participle in the Neuter gender, cf.

Klemensiewicz et al. [1955] p.432) rules out any possible ellipsis of the subject (no agreement in Person and Number is possible). This construction, derived historically from the subjectless passive and present also in some other Slav languages (e.g. in Russian and Ukrainian) is now interpreted as active, referring to an "indefinite, but close to 3rd Person referent", Klemensiewicz et al. [1955] p. 435. However, postulating the existence of an *underlying* subject in a deep syntactic representation, which is deleted after the agreement feature assignment takes place, glosses over the interesting but awkward facts of surface syntax in many languages (cf. Miller [1985] p.28).

Coming back to the controversial status of the German *es*, we have to note that it does not occur only in that one type of syntactic construction. The origins of the dummy subject *es* in Germanic languages have been studied by Brugmann [1917] and the manifold functions of *es* have been analysed in most studies of the German syntax. At least three different functions, and, in fact three different types of *es*, characterized by different semantics and/or different syntactic behaviour, must be recognized (examples in (17) quoted after Schatte [1982]):

(17)

es_0
- a. *es* wird gearbeitet
  'there is work going on'
- b. *es* steht ein Baum im Odenwald
  'there stands a tree in Odenwald'

es_1
- c. *es* donnert
  'it's thundering'
- d. *es* geht ihm gut; er bringt *es* weit
  'he is fine'; he'll do well'

es_2
- e. *es* freute ihn, daß du kommst
  'he was very glad that you are coming'
- f. er bedauerte *es*, nicht kommen zu können
  'he regreted not being able to come'
- g. das Buch ist dick und *es* liest sich schwer
  'the book is long and it reads with difficulty' .

Schatte [1982] p.42

Both es_0 and es_1 in (17) are, according to Schatte, semantically empty and do not refer to anything in the extra linguistic reality. They are only "innersprachlich logisch notwendig" as Schatte put it. However,

even these semantically homogeneous (i.e. semantically empty) types of *es* do not behave in a syntactically uniform way. While es_0 in (17a,b) may appear only in a sentence initial position (*Vorfeld*), with a finite verb taking the second place (*Mittelfeld*), this does not apply to es_1 and es_2. If anything else takes the sentence initial position in (17a,b), as in (18a,b), the *es* disappears:

(18) a. dort wird gearbeitet
'work is going on there'
b. dort steht ein Baum im Odenwald
'a tree stands in Odenwald' .

It must, however, be present in (19a,b,c) no matter what word order is chosen:

(19) a. jetzt donnert *es* schon wieder
'now it is thundering again'
b. ihm geht *es* gut
'he is fine'
c. weit bringt er *es*
'he'll do <u>well</u>' .

We may note here, that in (19a and b) *es* is a grammatical subject, while in (19c) it is a direct object. It does not have any real referent but it has a constituent status. Thus, es_1 has a syntactic function, es_0, on the other hand, has according to Schatte "satzordnende Funktion" in (17a) and "pragmatisch-kommunikative Funktion auf illokutiver Ebene" in (17b) (cf. also Engelen [1975]). We discuss this distinction in more detail in Chapter 3 (Subsection 3.2.2).

In (17e,f and g) *es* refers to another constituent of a clause or to a clause as a whole. It takes over its semantics, i.e. is not semantically empty, but does not have any constant semantics either. Thus it is used as a pro-form for another constituent and as such has constituent status itself.

1.3.3 **Syntax and Semantics of Impersonal Construction**

Any description of impersonal constructions poses so many difficulties because it involves both semantic and syntactic phenomena, and the mapping from one to the other level of representation is not always one-to-one. The authors of *Grundzüge einer deutschen Grammatik* [1981],

a recent grammar of German, make the following comment on the relationship between semantics and syntax:

> "Die Strukturen der semantischen Ebene bilden, obwohl eine isomorphe Abbildung nicht besteht, die Grundlage der Strukturen der syntaktischen Ebene." (p.500)

In this thesis we adopt the approach represented by the authors of *Grundzüge...* , typical of descriptions of German syntax since the time of Humboldt and developed also in the current theory of German grammar.

According to this approach the verb takes the central position in a clause. The complex lexical meaning of the predicate determines the semantic structure of the sentence, since it is the "Basis der ... Bedeutungsbeziehungen zwischen dem Verb and seinen Gefügepartnern im Satz, wie sie durch die Valenzstrukturen verkörpert und in den syntaktischen Strukturtypen des Satzes realisiert werden" (ibid.). Höhle [1978] presents a similar point of view. He discusses the notion of *lexical dependency* and states:

> "Der Begriff der lexikalischen Abhängigkeit, der mit dem der lexikalischen Selektion zusammenfällt, ist offenbar genau der Abhängigkeitsbegriff, der für die sog. Valenzlehre relevant ist, dort aber überaschenderweise weitgehend als unklar empfunden wird und zu ausgedehnten - und weitgehend ergebnislosen - terminologischen Erörterungen Anlaß gegeben hat." (p.19)

Höhle continues:

> "Es liegt auf der Hand, daß aus der (jedenfalls terminologischen) Gleichsetzung der lexikalischen Abhägigkeit mit einer 'Abhängigkeit' hinsichtlich allgemeiner syntaktischer Regularitäten, wie sie sich in allen mir bekannten Abhandlungen zu sog. Dependenzgrammatik dokumentiert, Konfusion entstehen muß." (ibid.)

He further associates *lexical dependency* with the unpredictability of the distribution features of the lexical elements, i.e. with the idiosyncracy of the case marking on the verb dependent NPs. Thus, again, he brings together notions from different levels of representation, considering them as causally dependent.

The lexical meaning of a predicate determines the structure of the entire sentence. We leave out the discussion of the arbitrary or semantically motivated character of the case selection, as this is a complex problem itself. An interesting discussion, based on data from Slavic languages and advocating the semantic motivation of case

selection, is presented in Wierzbicka [1980]

The general idea of a lexical predicate that must be associated with a specific number of semantic arguments, recalls the traditional definition of verb valency, as the ability of verbs (and in fact some other parts of speech) to open a number of *Leerstellen*, i.e. 'empty places' that must or may be filled in by certain linguistic entities. Sometimes, as e.g. in Charitonova [1976], Růžička [1978] or in the *Grundzüge einer deutschen Grammatik* [1981], the selection restrictions on the semantics of the verb actants are stated at one of the levels of the valency analysis. In the German linguistic tradition the notion of valency usually encompasses a set of interrelated problems comprising the predicate-argument structure (quantitative valency analysis), phrase-structure (qualitative valency) and the semantics of the arguments (*Selektionsrestriktionen* in Charitonova [1976]). This approach obscures the originally purely syntactic notion of valency. In Chapter 3 (Section 3.1.2), we further comment on the applicability of the theory of valency for our purposes. Here we merely indicate the importance of the fact that certain semantic arguments of the predicate are **predictable** or **inferrable** from its lexical meaning. Therefore, if certain pragmatic conditions are met (cf. Chapter 4, Section 4.2) and if language specific rules of syntax allow for this, the predictable arguments may be omitted without affecting the semantic interpretation.

Not all verbs behave in the same manner in this respect. It seems that the verbs with more precisely determined prototypical arguments/ participants correspond to the predicates of what Hopper and Thompson [1982] consider as 'highly transitive sentences'. They treat transitivity as a feature of the entire clause, not of the verb, and postulate a scale of transitivity according to 10 criteria such as e.g. number of participants, kinesis (action/non-action), volitionality, agency (prototypical/non-prototypical agents), affectedness and individuation of an object etc. High on this scale of transitivity are sentences where a prototypical, i.e. human, agent volitionally does something to an highly individuated object.

Slobin [1982] gives the following comment:

> "The important point is that Hopper and Thompson have, on linguistic grounds, identified a 'highly transitive clause type' characterized by a human-like agent, 'behaving actively, volitionally and totally to a definite or referential object'. The languages of the world have chosen

- in one way or another - to give special status to such clauses in their grammars." (p.411)

We might formulate the above statement in a more general way. It seems that the 'highly transitive clause type' is a subtype of a class of sentences that are used to refer to humans performing real or mental actions. It is for this class of sentences (or more precisely for this class of predicates) that the existence of external agency is either obvious or not necessarily required and the speaker may leave the interpretation open (i.e. omit the reference to the agent) since the hearer should be able to infer the missing information from elsewhere.

The available ways of demoting the agent-like argument from its neutral (in Indo-European) position of subject of an active clause are language specific and depend on the morphological and syntactic options possible in the language considered. Important factors are, among others, the function of the word order (i.e. its pragmatic or syntactic relevance) and inflectionality (i.e. repertoire of nominal cases, verb inflection and, consequently, the possibility of subject incorporation or omission).

From the above considerations it is easy to notice that for the interpretation of the notion 'impersonal' one more important distinction is necessary, namely, between syntactically and semantically impersonal expressions, which do not necessarily coincide with each other.

We have discussed so far syntactically impersonal constructions, i.e. constructions with the 1st participant of the verb demoted from the subject position (passive, reflexive and subjectless clauses) or constructions with verbs that do not have any arguments (weather phenomena). On the other hand, whether a given construction is to be treated as personal or non-personal from the semantic point of view "hängt nicht von dem Subjekt, sondern von dem Prädikat des Satzes ab und zwar von der lexikalischen Bedeutung des Verbs, das im Satz als Prädikat fungiert, oder des Adjektivs, das Prädikativ darstellt", Charitonova [1976] p. 59.

As long as the linguistic and non-linguistic context allows the human agent to be inferred from the lexical meaning of the verb, and as long as this interpretation is not ruled out by the surface syntax or by the agentive character of another participant, the expression referring to the agent may be demoted from the subject position, or omitted, and

the entire clause will still be given a personal interpretation.

In the rest of this thesis we discuss syntactically impersonal constructions which are assigned a semantically personal interpretation. Particular emphasis is put on the syntactically impersonal self-presentation of the speaker. The vast literature on this subject shows that the investigation of impersonal structures and referring expressions involves constant interactions between different levels of language description. In these introductory remarks we have not even touched on the problem of a pragmatic function assignment, although it is of major importance for sentence structure. Halliday commented on this problem in the late 1960's:

> "The clause is the domain of transitivity, of mood and of theme, all of whose options have to be accommodated in its structure; ... we cannot say that the structure of the clause is determined by its transitivity pattern, with other components providing only optional extras. The choice of subject, for example, depends largely on thematic options, since it is the participant functioning as theme rather than that functioning as actor that is normally chosen as the subject." (p.169)
>
> Halliday [1976]

Since the research presented in this thesis is based on texts from the domain of scientific communication, we are interested in a very specific pragmatics. We discuss the pragmatics of scientific communication in Chapter 2, and return to the question of pragmatic options important for the analysis of impersonal constructions in Chapter 3, where they are considered along with the syntactic and semantic characteristics of sentences.

From the above considerations it is apparent that the semantic *impersonalia*, i.e. verbs that describe events as caused or brought about by unknown or mysterious forces, will have no application to modern scientific, and specifically mathematical texts. Thus, in this thesis, we describe *syntactically impersonal* constructions and the way they are used as a means of indirect reference to human activities.

CHAPTER 2

PRAGMATICS OF SCIENTIFIC DISCOURSE

2.1 Review of Past Research on the Language of Science

2.1.1 Introduction

The research presented in this thesis has been carried out on scientific texts. This chapter is devoted to those problems of scientific communication that are relevant to linguistic research in general, and in particular to the problem of narration in science. The chapter consists of three parts. The first part comprises section 2.1 and presents the development and the current state of linguistic research on languages for special purposes (LSP). We outline major tendencies in the literature on LSP, indicating their deficiencies. We further discuss arguments for including a pragmatic component in the analysis of scientific communication in order to provide a functional explanation for the linguistic phenomena commonly associated with the language of science (Section 2.2). Finally, in Section 2.3, we focus on the notion of 'subjectivity'. We show how the complex approach to LSP, proposed in Sections 2.1 and 2.2, allows us to analyse 'impersonal constructions' in scientific texts.

2.1.2 Development of Scientific Language

The history of European science has its origins in ancient Greece. Greek was therefore the first language in the Western world to become a medium of scientific communication. To be a useful tool for scientist or philosopher (as far as this distinction applies to ancient Greece), Greek had to develop ways of describing and expressing more than the simple experience one could arrive at via the five senses. The major step in that direction was the development of abstract concepts and, consequently, the formation of abstract nouns by nominalisation of adjectives and verbs (cf. Snell [1960]). The Abstracta enriched the vocabulary with a new category of objects that could be given names - the objects of thought.

Since abstract concepts could not be affected by the imperfect senses, a higher degree of 'objectivity' was attributed by philosophers to them than to concepts denoting things in the real world.

Analysing the development of the scientific language in Greece, Snell [1960] makes the following comment:

> "Nur in Griechenland ist wissenschaftliches Reden autochthon; wo es später auftaucht, lebt es davon, daß es Griechisches übernimmt, übersetzt, weiterbildet". (p.73)

Greek, and then also Latin, served for centuries as international languages in European science. The Renaissance brought the breakdown of Latin as the language of international scientific communication. Some scientific studies continued to be written and published in Latin (in fact up to the 20th century) but the rising interest in national languages, and consequently their rising status, as well as the spread of secular education contributed to the growing use of languages other than Latin in the scientific domain. Many works were translated from Latin (some directly imitating Latin syntactic constructions), new books had already been written in national languages and, thanks to the invention of printing, scientific knowledge became more easily accessible. The easier exchange of scientific knowledge in the Renaissance period led naturally to the idea that human language should be improved to suit the needs of the time, and even to the idea that a new universal language might be created. Leibniz [1666] hoped that the newly devised universal symbolization of human thought, free from the deficiencies of natural language, would make it possible to solve controversies by means of a calculus of thoughts.

Similar ideas of universal or philosophical languages occupied other great thinkers of that time, such as Descartes and Bacon. Bishop John Wilkins, with the support of the Royal Society, published a comprehensive study on a universal language that was in fact a complex system of human knowledge representation (Wilkins [1668], for a short discussion cf. Robins [1979]; for a detailed presentation of the idea of universal grammar in the European linguistics, 1500-1700 cf. Padley [1976] and [1985]). Although in the 17th century none of the proposed projects became widely recognized or used in practice, the idea of a universal language of science must have influenced the form of scientific communication at least as much as it had influenced the community of scientists. This was reflected by the tendency to a greater unification of scientific terminology. The language of science attracts the attention of researchers for a variety of reasons. It naturally attracts the attention of scientists themselves who, through the analysis of language, investigate the methodology of their science. This is particularly true for those disciplines of science where language is more than just a transparent medium of communication, i.e. especially for philosophy and mathematics. On the other hand, the

interest of philosophers and mathematicians such as Frege, Russell, Tarski or Wittgenstein (to mention only some of those who have contributed to this field over the last century) natural language as a key to the nature of human knowledge, resulted in analyses that laid the foundations of new theories in linguistics.

Since mathematics may be viewed as a highly specialised language constructed to be as exact and precise as possible, it seems to be an interesting task to investigate how natural language is used in this science. In the following subsection we review the linguistic research on scientific communication and outline the approach to the problem of LSP adopted in this thesis.

2.1.3 **Review of the Literature on Languages for Specific Purposes**

The language of science attracted the attention of linguists relatively late. The Prague School linguists were the first to introduce the distinction between what they called different *functional styles* (cf. Beneš [1969], [1981]). They believed that the heterogeneous multilevel system of natural language has to be divided into subsystems according to the specific *functions* of language (on different classifications of language functions cf. e.g. Bühler [1934], Jakobson [1960], Halliday [1973]). Scientific style may be differentiated from that of the press, literature or everyday communication because it serves different purposes and therefore selects different means to achieve its goal.

The functional stylistic approach has given rise to a wide variety of linguistic analyses on LSP in the Soviet Union (cf. e.g. Kozina [1966], Solganik [1967], Budagov [1971], Mitrofanova [1976], Trojanskaja, [1979]). In that framework, scientific style is attributed such properties as precision, simplicity, logical structure of argumentation, emotional austerity, economy of expression, abstraction and generality of presentation. These general stylistic characteristics are then associated with the specific linguistic means employed in scientific communication. Here are some most often quoted features of the language used in science: high frequency of Genitive chains as attributes (to achieve terminological precision), neologisms with Greek and Latin morphemes, lack of certain word formation morphemes (e.g. suffixes used to express personal attitudes), use of suffixes unproductive elsewhere, limited use of standard figurative expressions (this cannot be generalised for all sciences), a complex system of

relations between the elements of a clause and between clauses, high frequency of participle-, infinitive- and gerundive- constructions, deverbal substantives, general tendency towards nominalisation ('nominal style'), semantic emptiness of verbs (preference for the 'copula + nominal predicative' constructions) etc. An exhaustive review of the research on LSP up to mid 1970's is given in Hoffmann [1976].

The functional-stylistic point of view brought new insight into linguistic research distinguishing between various *functional styles* or *registers* within the national language. This distinction was also a starting point for the sociolinguistic research on the varieties of language, i.e. on the group-, age- or profession-dependent *sublanguages*.

From the purely linguistic perspective, however, the stylistic approach as represented by the Prague School, is too general to capture the true relationships between the form and the function of language. Scientific style is a label covering a great diversity of language forms as used in different scientific disciplines. The linguistic characteristics of the abstract scientific style had therefore to be quite general to apply to the wide range of styles of different sciences. This approach has been criticised from the communicative point of view. It has been pointed out (cf. Hoffmann [1976]) that the rough classification into a limited number of styles does not take into consideration the situation specific and context dependent factors that often influence the choice of linguistic forms far more than abstract stylistic norms 'prescribed' for a particular functional style. This discussion had been summarized by Hoffmann's comment: "Die Fachsprachen haben Stil aber durchaus keinen einheitlichen" (p.73). (On recent developments in stylistics cf. Spillner (ed.) [1984].)

In British linguistics (the so called Neo-Firthian School) a concept of *register* has been developed to account for situational varieties of English (cf. e.g. Crystal and Davy [1969]).

Since the registers are not described in contrast to the language of literature, as was the case for most of the Czech and Soviet analyses, they are more suitable for the analysis of scientific texts. A brief comparison of the three approaches and a stylistic analysis of English for specific purposes (ESP) based on text typology (cf. Sandig [1972], Werlich [1975]) is given by Gläser [1982]. Her typology of styles in ESP, aimed at the communicative-pragmatic functions of texts, comprises

five styles:

- the academic scientific and technological style, represented by highly specialized literature or lectures, "addressed to 'insiders' of a particular field of knowledge";

- the popular-scientific style of semi-technical texts addressed to "the intelligent layman";

- the didactic style of textbooks that make scientific or technological subjects "understandable to the learner of a certain age group";

- the directive style "typical of texts which serve the directive function of language and the administrative force of the state";

- the practical style of everyday communication which, because of the subject matter, "touches upon LSP vocabulary".

Gläser [1982] pp.76-78

The style or register based approach is a perfect point of departure for a more complex analysis of scientific language because it allows for a functionally motivated division of language into communicative domains. Very often, however, this is also the end point of analysis and the researcher does not go into any detailed description of the correspondence between form and function of language in a specific domain. The 1981 AILA Symposium on Pragmatics in LSP made clear the need for of a wider approach to the linguistic analysis of technical and scientific communication (cf. Todd-Trimble & Trimble [1982], Weber [1982], Kalverkämper [1982], Ard [1982], Heslot [1982]). A good selection of papers on the relationships between the language as used in general communication (Germ. "Gemeinsprache") and the languages for specific purposes (Germ. "Fachsprachen") is given by Bungarten (ed.) [1981]. Unfortunately, although promising proposals have been made, a comprehensive study of scientific communication is still not envisaged.

From the layman's point of view, the most striking feature of scientific, technical or any highly specialised communication, is very often the specific vocabulary. Let us illustrate this approach with the quotation from Porzig [1957]:

> "Wenn wir etwa in eine Gesellschaft von Ärzten oder von Juristen oder von Fußballspielern geraten und die Leute beginnen von ihrem Beruf oder ihrem Interessengebiet untereinander zu sprechen, so hört unser Verständnis bald auf. Wir verstehen einfach die entscheidenden Wörter nicht mehr. Jeder Beruf, jeder Interessenkreis hat seine Fachausdrücke und seine besonderen Wendungen, die man gelernt haben muß und die der Außenstehende, der Laie, darum nicht kennt." (p.219)

If the special nature of the language of science resides merely in special terminology then the task of a linguistic analysis is to collect the special vocabulary. This was indeed the result of the lexical approach and language *minima* of particular sciences have been worked out via statistical analysis of word frequency in scientific texts. The major field of application of those minima or *basic languages* was LSP teaching, i.e. teaching material limited to a specific science or technology and intended for the students of that particular subject. The main centre of the linguistic research on frequency of lexical data in LSP in the 1970's was the group "Statistika reči" at the Institute of Linguistics, Academy of Sciences in Leningrad. This approach had also some followers in East Germany (cf. review of the LSP research in Hoffmann [1976] pp. 57n).

We may note here that the LSP research was often directly motivated by the didactic needs of a specialized, i.e. subject-oriented foreign language teaching (e.g. English for the students of medicine etc.) or professional interpreter training. Since English is the most widely used language in international scientific communication, there is not much interest among British and American linguists in LSP (and consequently in LSP research), although exceptions may be found (cf. e.g. early works by Savory [1953] and more recent research by e.g. Todd-Trimble & Trimble [1982].) Research in that field is concentrated in Germany (both East and West) and in the Soviet Union. It may also be worth noting that the rich (often theoretical) literature on LSP research and teaching, published mainly in German, is generally unknown to linguists working in other languages.

Frequency analysis, first applied to scientific vocabulary, was extended to research on morphology and syntax. However, the belief that there is no specific syntax of the language of science was dominant. Beier [1979] makes the following comment about the grammar of language for specific purposes:

> "Im Unterschied zur lexikalischen Ebene... hat die fachsprachliche Syntax keine speziellen Strukturen entwickelt, die es ermöglichten, sie in qualitativer Hinsicht von den anderen, nicht fachgebundenen Realisationen des Sprachsystems abzugrenzen. ...Ihr Wesen besteht... in einer spezifischen Häufigkeit und Verwendungsweise sprachlicher Strukturen, deren Auswahl weitgehend von den charakteristischen Inhalten und Funktionen fachsprachlicher Kommunikation beeinflußt wird." (p. 276)

A similar opinion has been expressed by Schmidt [1968]:

> "Es gibt keine eigene fachsprachliche Grammatik, es gibt lediglich eine bevorzugte Verwendung bestimmter grammatischer Mittel." (p.66)

In spite of these comments, syntax oriented research on LSP led to frequency analyses of various grammatical phenomena. The differences in language use between different disciplines of science within the same national language were studied and texts from the same discipline written in different national languages were compared (for a more detailed presentation of this problem cf. Stroińska & Zamojska [1985], for a review of results see Hoffmann [1976], Hoffmann & Piotrowski [1979], Kalverkämper [1982]). The major danger of this approach has been pointed out in Kalvenkämper [1982]:

> "Die Gefahr besteht..., daß sich die fachsprachliche Forschung bei ihrem Bemühen um Fachtextsorten in immer subtilere und pragmatisch differenziertere Einteilungen verliert. Sie sind letztlich Wiederspiegelung eben einer hochdifferenzierten Sachwelt, auf die die Fachsprachen-Forschung taxonomisch, also sorten-einteilend, reagiert, bzw. die sie nachvollzieht, ohne auch nur auf breiter Basis begonnen zur haben, sich Gedanken zur machen um die sogen. Fachlichkeit ihrer Sachwelt, und damit verbunden um die sogen. Fach*sprach*lichkeit von deren sprachlicher Erfassung, also von deren Vertextung." (p.112)

We shall argue (Chapters 4 and 5) that the common belief that scientific texts have the same syntax as non-scientific communication, (with differences due to the changed frequency only) is mistaken. The results of statistical research are often interpreted without bringing them into a wider perspective, i.e. ignoring the language-, science- and group-specific factors. Thus, texts (i.e. discourse) are interpreted in terms of a sentence grammar and this naturally leads to very superficial conclusions about some linguistic phenomena. This point is further discussed in Section 2.2.

Since the 1960's, when LSP research could be seen as "a peripheral curiosity within language pedagogy" (Høedt & Turner [1981] p.III), a

lot has changed in this field of linguistics. The last decade has seen an "explosion of interest" (ibid.) in language use in science and technology and this for a variety of reasons. Some linguists have chosen this field of language use as an interesting domain for purely linguistic research (cf. e.g. Gopnik [1972].

With the development of the sciences and the growing level of specialisation of scientists, new sociological problems have emerged. They partly result from the fact that scientific communication became incomprehensible to the layman, which, in turn, isolated the community of scientists from society. Some recent linguistic studies focus on reasons for the present situation and on possible solutions (cf. Bungarten (ed.) [1985]).

The most promising direction is, as was rightly noted by Hoffmann [1983], the "kommunikativ-textuelle, pragmatische Fachsprachen-Linguistik", as advocated by Kalverkämper [1982] p.109. The major objective of this approach is to concentrate on the questions of the inner structure of scientific and technical texts (spoken and written), that are seen as communicative acts. This line was originally proposed by Hoffmann [1976] who talked of LSP as a means of communication in specific communicative domains. Hoffmann's research concentrated, however, on the statistic analysis of language in different disciplines of science and technology, and on a comparison between it and the standard language.

In this thesis we adopt the communicative approach to the study of language in science. In the following sections we discuss the pragmatic approach to the analysis of scientific communication and show how it influences the investigation of the linguistic phenomenon of 'impersonality' commonly associated with the language of science.

2.2 Pragmatics of Scientific Discourse

2.2.1 Introduction

Scientific exchange of thoughts, like all instances of human communication, takes place in a specific situational context and obeys certain rules and conventions, different from those applying to everyday conversation. The context of the communication (i.e. communication situation, participants, their beliefs, presuppositions and attitudes) as well as group- and situation-specific rules always influence the linguistic form of the communication itself. This correspondence between the form of discourse and the communicative situation in general constitutes that aspect of linguistic analysis which belongs to the domain of pragmatics.

Pragmatics has been incorporated into the general framework of linguistic analysis only relatively recently. Most of the research on LSP was done before the rise of pragmatic theory in the 1970's, i.e. without reference to the context or any other pragmatic notions. This was also the case for functional stylistic analysis, which was carried out at the sentence level and did not take into consideration the situational context. Although the need for a pragmatic component in LSP research has been now recognized (cf. Proceedings of the 1981 AILA conference on pragmatics in LSP), a comprehensive study of the pragmatics of scientific communication is still to be done.

We believe that the analysis of reference and the apparent impersonality of presentation in scientific texts requires the analyst to go beyond the scope of a sentence grammar to discourse. This brings pragmatics into consideration and it is the aim of this section to present an outline of the pragmatics of scientific communication in general and of mathematical discourse in particular. (Some aspects of this problem have been presented in Stroińska [1986].)

2.2.2 Gricean Maxims and Scientific Communication

Since the pragmatics of scientific language has not yet been investigated in any great detail, we begin by comparing the pragmatic features of scientific communication with those of everyday communication. As a testing device, we may use the Gricean maxims of conversation (cf. Grice [1975]) which were originally proposed for

colloquial language. We do not attempt to give an exhaustive comparison of pragmatic features characteristic for scientific and non-scientific communication but rather to point out the differences that seem to be relevant for linguistic analysis.

Let us briefly recall for convenience what we refer to as Gricean maxims of conversation. These are:

1. Cooperative Principle : Make your conversational contribution as requested;
2. Maxims of Quality : Try to make your contribution one that is true. Do not say what you believe to be false. Do not say what you lack adequate evidence for;
3. Maxim of Quantity : Make your contribution as informative as required;
4. Maxim of Relation : Be relevant;
5. Maxim of Manner : Avoid ambiguity and obscurity of expression.

The Gricean maxims have often been criticised as being ideal and unrealistic. Indeed, natural everyday conversation does not always conform to their patterns and requirements. Speakers may agree with Gricean principles in theory, but they violate them in everyday practice. This raises doubts as to whether they apply to natural language communication. Some critics even suggest that the maxims may "at best be valid if applied to an exchange between computers"... (Riniker [1979] p.60).

A more constructive way of using the Gricean maxims is to consider them as a set of principles for the evaluation of hypothetical interpretations of an utterance. In order to interpret an utterance, we assume that the speaker wants to say something true and relevant and that he does it in the best and most economical way. We shall give up these assumptions only if there is a reason - e.g. previous experience - not to trust the speaker. Should this be the case, we modify or adjust our principles of evaluation to avoid being misled by the speaker.

It is clear that the Gricean maxims apply to scientific communication more readily than to colloquial conversation. The reason for this may be the fact that both the Gricean maxims and the principles of scientific exchange of thoughts define an 'ideal communication'.

If we try to summarize the maxims, we could say that they simply

characterize good speech or a well-trained speaker. As such, they could be derived from the principles of classical rhetoric, which translates as 'the art of using words in the most efficient way'.

Going back to Greek rhetoric we find that there were two traditions: one deriving from the sophists, the other from Aristotle. The sophists developed rhetoric as an art of "giving effectiveness to the speaker", while Aristotle's rhetoric was conceived as the art of "giving effectiveness to truth" (Baldwin [1928] p.3). However, despite Aristotle's efforts to fight the sophistic style of rhetoric, it is the latter that survived as a part of general education. This is also why the attribute 'rhetoric' often implies insincerity and exaggeration (a brilliant discussion of differences associated with the notions 'rhetorician' and 'orator' in various European languages is presented in Klemperer [1957]). The Aristotelean tradition, on the other hand, could survive only where the search for truth was declared a major goal, and this characteristic often applies to sciences, though with different degrees of relevance for different disciplines.

Scientific communication in the European tradition, especially in the exact sciences, follows Aristotle's rhetoric. It is, therefore, an example of human communication naturally fitting Gricean principles of conversation.

One may ask: why talk about scientific texts in terms of conversation? Reading a scientific article is indeed a peculiar form of conversation but some interaction between the author and the reader can still be traced (for a comparison of texts on the basis of the participant relationships between the writers and reader of the text cf. Huddleston, et al. [1968] or Smith [1985]). Writers usually have in mind an imaginary reader for whom the paper is written. Coler [1963], discussing the structure of scientific papers, comments: "if W (i.e. writer - M.S.) is a competent and aware worker in the field, the resemblance between R (i.e. imaginary reader - M.S.) and actual readers will obviously be more than fortuitous" (p.231). Coler introduces also the concept of 'encyclopedic reader' i.e. "reader who has all prior existing knowledge regarding S (subject) at his command" (p.232).

The interaction between the author and the reader is 'delayed' as is the case for most forms of written discourse. The delay in interaction causes a possible difference between the situation of text production

(context of writing) and the situation of text interpretation (context of reading). This fact may lead to the assumption that the scientific text is 'situation-independent', but this is not quite right. Rather, a scientific text is 'self-contained', i.e. it explicitly or implicitly includes all the information required for a correct interpretation, so that the changing situation does not affect it, and does not cause ambiguity. It is, however, not 'situation-independent' since it takes into account both the context of writing and the context of reading. For example, the arguments of the author are meant to influence a specific, contemporary reader or a group of such readers, but at the same time they are presented in such a way that they can be followed by any future reader who has the required and explicitly indicated knowledge. Scientific texts fall therefore into the category of what Nystrand [1982] calls "endophoric", i.e. explicit and "self-contextualizing" texts, as opposed to "exophoric texts", that are cryptic due to their context dependency.

Thus, scientific texts may be seen as part of a larger communicative interaction within the community of scientists. Francis [1961], discussing the rhetoric of science, makes the following statement:

> "Science, though it can be abstracted from any particular human being, is a part of human culture. It is a kind of human behaviour. As such, it occurs in a social situation." (p.7)

He further suggests that 'scientific acts' shall be looked at "as human behaviour which necessitates communication among scientists" (p.9). We may thus assume that as long as we have a speaker addressing a specific (even if imaginary) audience with a specific purpose (and with a possibility of direct or indirect response) we may talk about a conversational or discourse interaction, extending simply the notion of conversation beyond an everyday verbal exchange. (For further discussion of the notion of 'audience' both in rhetoric and in linguistics cf. Nystrand (ed.) [1982].) The fact that the Gricean maxims of conversation, unrealistic elsewhere, are obeyed by scientific discourse, may be seen as an indirect argument for the view that scientific text is more than a collection of sentences, i.e. that it must be analysed in terms of discourse.

2.2.3 Pragmatic Characteristics of Scientific Communication

We have mentioned the feature of being 'self-contained' as a characteristic of scientific discourse. Let us now examine other pragmatic properties of scientific communication in general.

Scientific discourse may be characterized as follows. It has:

1. a well-defined subject matter or topic, usually indicated in the title;

2. a well-defined 'audience'. We use the notion of 'audience', taken from classical rhetoric, to describe intended readers of a book (paper, etc.) or people gathered in a lecture hall. They are not a random sample of society and represent the same or related discipline of science as the author (we ignore here the case of popular-scientific papers or lectures and other instances of non-academic communication);

3. easy-to-define assumptions about the knowledge of the audience. We call this knowledge 'level of specialization'. The author is usually well aware of the level of specialization of his audience and may adjust the way he expresses his thoughts according to that level. In this thesis, we concentrate on mathematical discourse with a high level of specialization;

4. a well-defined purpose. This may be a didactic purpose in the case of an academic handbook or a student lecture. The scientific communication may have an evaluation purpose in the case of a discussion of the arguments for and against a particular theory. Its purpose may also be the presentation of the author's own work and results. In some scientific disciplines, especially in the social sciences, the communication may be of a persuasive character. Discourse purpose may be associated with the traditional rhetorical distinction between text genres - expository, procedural, narrative, hortatory, etc. However, although we may talk about the general purpose of a specific instance of scientific communication, each text needs further subdivision into smaller units with their particular purposes (e.g. Heslot [1980] distinguishes between Introduction, Materials & Methods, Results and Discussion as constitutive parts of scientific

papers in experimental sciences, each associated with a specific selection of linguistic phenomena);

5. extended time for sentence production and interpretation, especially in the case of writing and reading scientific texts;

6. the property of being 'self-contained', as mentioned before.

The features listed above describe the situation(s) in which scientific communication takes place, the overall purpose of the communication and the participants in the discourse. They refer to very general properties of this communication and we call these features 'external requirements' of a successful scientific communication.

2.2.4 **Mathematics and Mathematical Discourse**

Apart from these external requirements, each discipline of science sets up its own internal conditions. We shall concentrate on the internal properties of mathematical discourse.

In section 2.1 we argued against the vague notion of 'scientific style', on the ground that, due to the steadily growing specialization of the sciences, it does not correspond to any linguistic reality. Now, when we talk about 'mathematical discourse', we might be accused of making the same mistake. The development of mathematical theories and their applications is so enormous that people often talk about 'mathematical sciences' instead of just one mathematics. It is not surprising, because, while most sciences are at most a few hundred years old, the history of mathematics is measured in millenia, and some fundamental advances go back as far as ancient Greece. Over the 25 centuries of its history, and despite all the radical changes in the field, mathematics has remained a unique human activity, one that escapes the simple classification into arts and sciences. Mathematics is unique among sciences (e.g. it is not an empirical science) and it is a peculiar form of art. Nevertheless, mathematicians, e.g. Henri Poincaré [1948], Paul Halmos [1968], write about the feeling of mathematical beauty, harmony and elegance and often judge mathematical results according to aesthetic criteria. Halmos [1968] argues that mathematics is "a creative art because mathematicians create beautiful new concepts", because they "live, act and think like artists" and because they regard mathematics as art. The controversy on the dual character of mathematics is not the only one. There is no consensus on

yet another fundamental question of methodology, namely whether mathematical truths are discovered (the idea of revealing mathematical reality advocated by Plato) or invented by the human mind (cf. discussion of the above controversies in Alexandrov [1963], von Neumann [1947], Whitehead [1956]).

Despite the fact that some basic questions about the methodology of mathematics remain open, the mathematical sciences have developed an enormous potential of knowledge. However, the situation is complicated by the growing isolation of modern mathematics from society. To visualize the gap between the current level of development in mathematics and the mathematical education of the general European public, it is enough to say that the secondary school programme does not usually go beyond the XVIII century (one of the few exceptions being the set theory), thus leaving out the great and revolutionary achievements of the last two hundred years. There are also hardly any popular-scientific publications that would make this specific domain of human knowledge more accessible for educated non-specialists. One of the very few exceptions in this field is the collection of essays on modern mathematics edited by Steen [1978], where deep concern is expressed about the difficulties facing mathematicians communicating with the society. The isolation of the mathematical community has also a linguistic dimension. In everyday conversation it is impossible to guarantee that two people have exactly the same interpretation of any word uttered. They would have to agree about the definitions of the key words first, but even in this case they could attach different emotional value to them, and this would remain beyond the scope of definition (this may be explained in terms of the distinction between intensional versus extensional identity). On the other hand, for everyday communication it is enough if people share just the core meaning of the words they use. However, the higher the level of abstraction of the subject matter and the less "derived from the senses" the notion is (to adopt a phrase of Russell's), the greater is the likelihood that two people will interpret it in a similar way.

Here, the other-worldly vocabulary of mathematics, which makes any communicating with society almost impossible, proves very useful. Mathematical concepts are closest to the ideal of abstraction. Very often not even analogy could make mathematical concepts closer to any real human experience. They are, nevertheless, well-defined and the speaker has a "discriminating knowledge" (cf. Evans [1982] p.89) of the

objects he refers to using mathematical vocabulary, i.e. he has the capacity to distinguish the object of his judgement from all other objects. The meaning of a mathematical term may be identified with its definition (i.e. with a set of properties or requirements that must be met by the referent) and is therefore likely to be the same for the speaker and the hearer. In addition, preliminary assumptions concerning the discourse topic must be made explicit (the assumed level of knowledge required from the audience is indicated), and there are certain conventions for each science as to how this is to be done. (Ard [1982] refers to that indication ascribing to it the 'context building' function.) The well-defined meaning of the notions used and the lack of figurative expressions other than the standard jargon, does not leave much space for ambiguity.

Further, as mathematics is a deductive science, it has developed a highly sophisticated system for drawing inferences. These rules of inference (logic) and the highly formalized process of mathematical proof do not fully prevent false statements and do not give a ready decision on truth values (cf. Gödel's concept of "undecidability") but they naturally make the Gricean maxim of quality "Do not say what you lack evidence of" easier to obey.

We might refer here to the concept of truth developed by Alfred Tarski both for everyday language and for formalized languages. Tarski states that there are difficulties with defining truth in colloquial language. "With respect to this language not only does the definition of truth seem to be impossible, but even the consistent use of this concept in conformity with the laws of logic" (Tarski [1956] p.153). For formalized language, on the other hand, it is possible to introduce a consistent and logically correct use of this notion, even if it is not always possible to decide whether a particular statement is true or false.

The internal features of mathematical discourse that we have outlined so far may be summarized as simply the features of a deductive science. We have:

1. well-defined terminology,
2. high level of abstraction,
3. explicitly given assumptions and axioms,
4. formalized rules of inference,

5. consequences (derived from assumptions via the rules of inference).

The question of redundancy in mathematical discourse, i.e. the applicability of the Gricean maxim of quantity, was addressed by Ard [1982]. Ard points out that the strictly mathematical (i.e. symbolic) and the verbal part of mathematical text often paraphrase the same 'theme'. He quotes the advice of the mathematician Menahem Schiffer as to how to write mathematics (cf. Schiffer [1973] p. 58):

> ..."Give the important theorems in two stages, the heuristic argument and the rigorous logical change."

This indicates that the paraphrase serves largely to facilitate understanding of the complex concepts, i.e. is by no means redundant from the communicative point of view. Ard makes also an interesting observation about the general interpretation of the informative value of a text. He says that it would be 'absurd' to interpret a mathematical text including all inferences and deductions that could be based on it, since all theorems, lemmas and corollaries could be deduced on purely logical grounds from the set of definitions and axioms. Therefore, anything in a given mathematical text, beyond these axioms and definitions, would be obvious, i.e. redundant. This observation again confirms the necessity of placing mathematical discourse in a correct situational and temporal context.

In a deductive system of mathematics, there should be no space for lexical ambiguity or indeterminacy and we could say that the Gricean maxims, as 'intellectual requirements' (cf. the concept of 'intellectual requirements' in Chisholm [1981] pp.176n), are implied by the specific rhetoric of mathematics. They follow naturally from the inherent conditions of discourse in the deductive sciences. In this sense we might call mathematical discourse 'ideal' from the pragmatic point of view, because it meets the appropriateness conditions on discourse in general. The external requirements spelled out before may then be regarded as specifying a *restricted context* which guarantees that scientific communication will be successful. (On the concept of language use in a 'restricted semantic domain' cf. the selection of papers in Kittredge & Lehrberger (eds.) [1982]. On a possible formalization of language use in the restricted context of science cf. Bellert & Weingartner [1982] in the above mentioned publication.)

There are, however, some 'ambiguity-like' phenomena in mathematical discourse. They may be caused by e.g. deriving intuitions about concepts from their names or from mathematical jargon. For example many terms are apparently 'dynamic' and may present as dynamic certain mathematical relations which in fact are not so. This concerns especially verbs used in mathematical expressions such as:

a. "a series of points converges..."
b. "data is projected (or mapped) onto the surface"
c. "embedding a covariate (in a family)..." .

We may illustrate this type of interpretational ambiguity with a more familiar example from linguistics. In GPSG features associated with syntactic categories may be 'passed down' the tree or may 'go up' the tree according to certain principles. It usually takes a while to realize that no real 'movement' of passing down or going up is involved - the features are simply distributed according to these principles. (On 'dynamic' terms cf. also Hockett [1954].)

2.3 Impersonal Rhetoric of Science

2.3.1 Subjectivity versus Impersonality in Science

In Section 2.2 we have talked about general features of scientific communication and about internal properties of mathematical discourse which follow from the inherent requirements of a deductive science. There is yet another phenomenon distinguishing scientific and non-scientific communication that we have not mentioned as a pragmatic feature because its nature is philosophical rather than strictly pragmatic. It is the phenomenon of *subjectivity* and we consider it in more detail because of its deep linguistic implications.

Subjectivity is a natural feature of any speaker - or situation-dependent discourse, and since practically all instances of natural language communication are egocentric, we may merely talk about different degrees of subjectivity. In fact, some philosophers argue that the human mind naturally "applies a constant subjective perspective to the world" (McGinn [1983] p.69) - the property of being 'constant' refers basically to the constant linguistic meaning of indexical expressions that build up the 'logic of context'. In everyday communication subjectivity is quite common and may even be an inherent element of the structure of some literary works (on subjectivity in the literary texts cf. Jay [1984], on apparently impersonal narration cf. Banfield [1983]). In science, however, subjectivity is regarded as a vice. Bertrand Russell [1946], who adopted a rational approach to science, expressed this as follows:

> "Scientific knowledge aims at being wholly impersonal, and tries to state what has been discovered by the collective intellect of mankind."

The same point has been made more recently by McGinn [1983]:

> "Science aims for 'neutrality' in its depiction of the world : it should not be possible to read off from a scientific theory any peculiarities of its propounder",

and further:

> "It is a closely connected point that perception cannot represent the world as it is (entirely) 'independent' of the perceiver - but just this is what a scientific description aspires to achieve." (p.111)

It seems that McGinn translates the idea expressed by Russell into terms closer to those of linguistic description. He concludes that the representation of the world by humans can be "innocent of subjective elements" if it is presented in a non-indexical mode. The non-indexical mode of presentation is connected with the condition of dealing only with the 'primary qualities' of objects, i.e. with those properties that do not consist in the objects' disposition to produce sensory experiences in perceivers (the distinction between primary and secondary qualities was introduced by Locke and further analysed by e.g. Jackson [1929], Bennett [1971] and McGinn [1983]).

The "desire to escape from subjectivity", as Russell [1946] p.17 put it, may lead some scientists, especially those adopting the positivistic approach, to make the language they use as 'impersonal' as possible - we use here the notion 'impersonal' as opposite to 'subjective'. Thus, they eliminate, or at least try to eliminate, everything that may be considered as subjective and therefore non-scientific, i.e. first of all any direct reference to themselves and to when and where the text is produced. As a result, there are hardly any instances of direct, i.e. 1st Person Singular, self-reference. Dates and geographical locations are substituted for the subjective, deictic *here* and *now*, and other 'egocentric particulars'. Since Tense is also deictic, the general Present Tense is a preferred convention.

The requirement to be 'impersonal' or 'neutral', i.e. not to be subjective, is a natural rhetorical imperative for most sciences. To a certain extent it may again be derived from Aristotle's principle of giving effectiveness to truth. Although some scientists write in a more individual manner, each science still has its standard rhetoric, and the standard rhetoric of mathematics has been impersonal for centuries.

We may illustrate the 'impersonal' tendency with the example of Carl Friedrich Gauss, the great 18/19th century mathematician, who for many years kept a private mathematical diary, published only recently, where he recorded his own discoveries. Even these private notes, written in Latin, often have the impersonal form. Here are two examples of his style:

1. with an impersonal construction

Numerorum primorum non omnes numeros infra ipsos residua quadratica esse posse demonstratione munitum

'it can be shown that not all quadratic remainders of prime numbers are themselves prime'

2. with 1st Person Plural, *we*

Conspicuum exemplum novimus et quod congruum videtur. Confidamus

'we know about an extraordinary example which seems to agree with this. let us hope' .

Gauss, [1981] p.41, 43

2.3.2 **Self-Reference in Impersonal Narration**

We shall now consider the problem of subjectivity and self-reference in the language of science in more detail. This topic has a rich philosophical literature. Philosophical theories of 'first-person-sentences' concentrate on the intentional character of reference and the subjective character of human knowledge (cf. e.g. Evans [1982]). The apparent idiosyncracy of certain 1st Person related statements is the central point in much of the Philosophy of Mind, Solipsism, Scepticism, Private Language theories and other doctrines. The philosophical approach to self-reference, however, takes not much interest in real language data, basing itself mostly on the properties of isolated sentences. Thus, they are of limited relevance for the analysis of discourse phenomena, and we mention only the major theoretical points of the philosophical analysis of self-reference.

First-person-sentences may be considered as 'direct-attribution' of a certain property to the speaker by the speaker (cf. Chisholm [1981] pp.27n). The properties that are most commonly attributed by the speaker to himself are those properties that are 'empirically certain' for him, i.e. "immune to error through misidentification" (cf. Evans [1982] pp.215n); these are first of all his 'states of mind' and other mental self-ascriptions, such as thinking, feeling or believing as experienced by him.

Talking about scientific communication, we shall be mainly interested in those states of mind which are related to beliefs and knowledge. We may distinguish several different epistemic levels for accepting or

rejecting a proposition, i.e. deciding about its truth value. 'Being evident' is the level which distinguishes knowledge from true belief that is not knowledge (cf. Chisholm [1981] pp.76n; on the semantic status of *know* and *believe* cf. Wierzbicka [1972], on the 'cognitive vocabulary' of scientific texts and on its semantic interpretation cf. Bogusławski [1981]). Restricting our analysis to the highly formalized language of mathematics, we may assume that what the author says is "beyond reasonable doubt" for him (Chisholm [1981] p.78), and he may prove, according to the codified rules of mathematical reasoning, that he is right. The restricted context of a deductive science brings therefore a new quality into the discussion of subjectivity.

The linguistic question which has to be answered is: Is it possible to achieve successful self-reference using devices other than first-person-sentences? Strawson [1959] p.158, for instance, doubts that an object could be identified if it is referred to by some sort of 'indefinite description'. This is because indefinite descriptions either do not distinguish one term from another or do not definitely identify a given term. It seems that this general assumption does not hold in the specific context of scientific communication. We come back to Strawson's considerations on self-reference towards the end of this section.

It has been said that scientific rhetoric avoids the use of the 1st Person Singular. The pronoun 'I', however, is the most economical, but not the only possible way of expressing self-reference (cf. Coval [1966]). Therefore, authors who avoid 1st Person Singular have to exploit other possibilities offered by the syntax of the language they use. Of particular importance in this regard is the fact that the language is used in a pragmatically and semantically restricted domain which may influence the referential properties of some expressions.

In German mathematical discourse, we may find many forms of non-1st-Person-Singular self-reference. These are e.g. the 1st Person Plural pronoun *wir*, the indefinite personal pronoun *man*, impersonal passives, reflexive and infinitive constructions and other syntactic structures with the acting participant demoted from the grammatical subject position, as well as some other means of non-direct self-reference such as speaker restricted names, e.g. *der Autor*.

The use of 1st Person Plural forms when referring to one's own

acitivities or experiences as a member of a group has been addressed by philosophers who discuss the question of whether there could be a 'group mind' as opposed to individual minds. Strawson [1959] refers to this problem asking whether it would be possible to "construct the idea of a special kind of social world in which the concept of an individual person is replaced by that of a group". In this context he further discusses the use of plural pronouns *we* and *they* as referring to those groups. He concludes:

> "...these are not genuine plurals, they are plurals without a singular... . They may also refer to elements in the group, to members of the group, but exclusively in terms which get their sense from the parts played by these elements in the corporate activity." (p.113)

What is interesting for present purposes is that Strawson's observation applies to the language of science. The plural *wir* used in scientific discourse may have, as one of its functions, reference to a 'group mind' of the community of mathematicians, when the speaker talks of the common body of mathematical knowledge.

We provide the full description of the use of pseudo-plurals and other linguistic means of 'indirect self-reference' employed in German mathematical discourse in Chapter 4. In Chapter 3 we introduce the theoretical model for interpretation of indirectly referring expressions that allows us to analyse them in a complex way, i.e. taking acount of semantic, syntactic and pragmatic factors, as well as of their mutual dependencies.

CHAPTER 3

PREDICATE FRAMES

3.1 Knowledge Representation and the Concept of Frame

3.1.1 Introduction

In this chapter we present the predicate frame model which we use to analyse the referring expressions in scientific texts. The chapter consists of three parts. First, in Section 3.1, we review the literature on *frames* and related concepts. In the second part, Section 3.2, we present and define the concept of a *predicate frame* (further abbreviated as PF). In the third part, Section 3.3, we use the model to determine the elements necessary for a successful interpretation of referring expressions and demonstrate how the predicate frame model handles non-isomorphic correspondences between the syntax and semantics of a sentence.

3.1.2 Review of the Literature on Frames

The notion of *frame* appeared simultaneously in sociology and in the field of Artificial Intelligence (AI). Frames were first introduced in sociology by Goffman [1974], but the term *frame* had already been used, in much the same sense, in Bateson [1955]. The aim of Goffman's work was to "isolate some of the basic frameworks of understanding available in our society for making sense out of events" (p.10). He distinguished between two basic ("primary" as Goffman put it) frameworks for interpreting events: natural and social. Natural frameworks identify events that are perceived as undirected, not involving "any willful agency" (p.22). Social frameworks provide ways for understanding events where some sort of "will, aim, and controlling effort of an intelligence, a live agency, the chief one being the human being" (ibid.) is involved. Goffman assumed that *situations* are defined according to principles of organization which govern *events*.

He then defined *frames* as basic identifiable elements of a situation, as sets of elements we necessarily identify in a stereotypical situation of a certain kind. Individuals may be unable to define or describe their situational frameworks but they easily apply them in practice to interpret events they are involved in.

The concept of *frame* as a formula to organize knowledge representation, was introduced in computer science by Minsky [1975] in his influential paper *A Framework for Representing Knowledge*, where frames were applied

to computer vision. Frames were soon applied to all sorts of computer processing of information. There is a vast literature on frames and frame-based text processing, written mostly in the late 1970's. An exhaustive review of this literature is beyond the scope of this chapter and we indicate only those developments in the field of AI which seem to be useful for our research. A comprehensive summary on frame conceptions applied to text processing and a good selection of papers on the most important topics is presented in Metzing (ed.) [1980] and Barr & Feigenbaum (eds.) [1981].

The main point in Minsky [1975] was that the processes of recognition and comprehension are 'expectation-driven' and that the modelling of these processes on the computer requires special devices for the organization of the knowledge base and special devices for selecting relevant fragments of that knowledge (i.e. 'frames' relevant for the situation to be analysed). In these situational frames the elements necessary for 'understanding' a particular situation are specified. When processing information, the model fills the frame with data available, according to the frame specifications. Thus, when correctly selected, frames provide guidelines for information processing.

Minsky's frame concept has stimulated research on writing and implementation of knowledge representation languages (cf. Goldstein & Roberts [1977], Bobrow & Winograd [1977]) and on formal analyses of some selected linguistic problems, as for instance 'discourse links' (cf. Rosenberg [1980]) or extended use of words (cf. Wilks [1980]). Frames and related concepts (as e.g. *scripts* and *plans* in Shank and Abelson [1975], [1977] and in Lehnert [1980], *action-frames* in Charniak [1976], [1980] etc.) were employed in the analysis of 'situations', 'events' or 'stories', and the psychological validity of the frame theory was experimentally tested.

Our concept of *predicate frame* has some similarities with those proposed in Minsky [1975], Bobrow and Winograd [1977], Hayes [1980], Rosenberg [1980] etc. It is, however, applied to the analysis of predicate-argument structures and, therefore, differs considerably with respect to detail. Describing the predicate frame in Section 3.2 we refer to the use of the term *frame* in frame theory as developed in Artificial Intelligence and point out general similarities in form and differences in function.

Long before the idea of frame-like structures for knowledge representation became popular in AI research, formally similar concepts had been developed in linguistics. The most influential theories in this field of linguistics were Dependency Grammar as proposed in Tesnière [1959] and Case Grammar as developed by Fillmore [1968a], [1968b], [1971], [1975]. However, studies on the relationships holding between a given verb and the noun phrases that accompany it to build up a (grammatically correct) clause, have been in the focus of attention of language philosophers and linguistics for a relatively long time. Linguistic research of the verbal system in, e.g., German followed many different lines, the most interesting from the point of view of this study being the analysis of the verb's syntactic value according to the number of *objects* it needs to constitute a clause. Already at the end of the 18th century, Meiner [1781] divided verbs into three groups : "einseitig-unselbstständige", "zweiseitig-unselbstständige" and "dreiseitig-unselbstständige", i.e. those that need one, two or three complements respectively. The most interesting point in this approach was the equal treatment of the subject and other arguments. Meiner's approach differed from that represented in later research on German, e.g. in Heyse [1914] and Behagel [1924], where verbs were divided into "absolute" (i.e. those taking subject only) and "relative" (i.e. those taking other arguments also). Thus a different status was assigned to subjects than to other complements of the predicate. Probably the best known formula proposed in German linguistics for describing the syntactic incompleteness of some parts of speech in terms anticipating valency theory, was the one in Bühler [1934] who recognized "daß die Wörter einer bestimmten Wortlasse eine oder mehrere *Leerstellen* um sich eröffnen, die durch Wörter bestimmter anderer Wortklassen ausgefüllt werden müssen" (p.173).

A new insight into the nature of predicate-argument structure was given by Tesnière [1959] whose Dependency Grammar was designed to reveal hierarchical dependencies hidden behind the linear order of natural language structures. In Tesnière's model, the verb is the point of departure for the analysis of sentences. The nominal elements accompanying the verb can be divided into the *subordines immediats* of the predicate, further subdivided into the *actants* and *circonstants* (i.e. the participants in an action described by the verb and the circumstances of that action). According to Tesnière, only the *actants* are properly

required and determined in number by the verb. The ability of verbs to require complements (i.e. *actants*) Tesnière calls *valency*. In his model, subject is just one of the actants, i.e. it has lost its special status (traditionally based on semantics). This purely syntactic treatment is supposed to facilitate description of the dependencies within the sentence, as well as the description of the active-passive opposition. The model also allows for some valency positions to be not filled, i.e. to remain *inemployees* in the actual clause, giving a new insight into the phenomenon of syntactic ellipsis. The same point is made by Hockett [1959] p.252.

Valency theory has been applied to the description of German by Grebe [1959], Schmidt [1963], [1965], Brinkmann [1957/58],[1971], Erben [1972], Admoni [1982], *Grundzüge...* [1981], *Duden Grammatik* [1984] and many other authors. A compendious critical review of the subject is presented in Helbig & Schenkel [1973] and more recently in Abraham [1978] and Helbig [1982]. Although the above mentioned authors adopt various approaches to the nature of hierarchical dependencies in the predicate-argument structure (e.g. as to the place of semantics in the model), the common point is the central position of the verb and taking syntax as the starting point of the description. Helbig & Schenkel [1973] point out that taking semantics as primary in the determination of verb valency presupposes one-to-one mapping between structure and content, which is obviously not the case in language (p.18).

Recognizing the verb as a central component of a sentence, Fillmore [1968] proposed another approach to the primary system of dependencies within a sentence. Fillmore's early model was conceived merely as a small revision to the theoretical framework of transformational grammar and an alternative to the generative semantics (as developed by e.g. Lakoff [1965]). Instead of a decomposition of semantically complex predicates into a string of primitive predicates, as was proposed in generative semantics, Fillmore developed a framework based on the concept of *deep cases*, i.e. semantically relevant syntactic relationships that hold between the verb and each noun phrase associated with it. For any verb, the cases co-occurring with it form an ordered set, called a *case frame*. The inventory of cases proposed by Fillmore [1968] consisted of:

- Agentive : the instigator of an action, typically animate;
- Instrumental : the immediate physical cause of an event, inanimate force or object;
- Dative : something animate being affected;
- Objective : semantically most neutral case, objects affected by an action;
- Factitive : something resulting from an action;
- Locative : location of an action.

A revision of the inventory in [1971] introduced the Experiencer case instead of Dative, and divided the Locative into Source and Goal. Case frames not only indicated what cases may co-occur with a particular verb but also indicated whether they can be omitted (facultative valency). Fillmore also proposed a Case Hierarchy to account for the regular syntactic changes in a sentence when some cases were missing, e.g. conditions for an Instrument to become a subject. The case frames gave an elegant account for e.g. paraphrase relations (the same case frame corresponding to different syntactic representations) or word pairs as: *buy* and *sell* or *teach* and *learn* (the same basic meaning but different case frames). Although it was Fillmore's ambition to keep the case number as low as possible, his model used up to 9 cases and still could not provide an exhaustive description for all predicate-argument structures. (We refer to this point in more detail in Section 3.2.)

In his linguistic analysis, Fillmore took into consideration the psychological research on human memory and cognition processes. He notes, (Fillmore [1975] p.124), that the *frame* idea goes back as far as the concept of *schema* in Bartlett's research on remembering in the thirties (cf. Bartlett [1967]), and refers to Berlin and Kay's [1969] study of the colour terms and to the analysis of *natural categories* by Rosch [1973]. Fillmore's Case Grammar, operating with semantic primitives, could readily be translated into the *semantic networks* in the AI research on natural language processing. (On the implementation of Case Grammar in AI cf. Barr and Feigenbaum [1981], IV C4.) The main idea of Case Grammar, the one that we shall adopt in our research on reference, is that verbs provide *templates* within which even incomplete sentences can be understood. This approach relates to much of the current developments in the field of Artificial Intelligence, where the notions of *prototypes* and *analogy* proved to be very useful in modelling problem solution and language understanding processes (cf. Proceedings of the 7th European Conference on AI [1986]; on analogy matching cf.

Owen [1986] in the above source).

The predicate frame model resembles linguistic concepts from various theoretical frameworks. The aim of our research is to describe a model for interpreting reference patterns in scientific discourse. To achieve this specific goal, we do not follow any particular linguistic theory. Interpreting reference involves taking account of linguistic phenomena from various levels of language description, such as semantic verb classes, types of participants, syntactic options valid for a particular language, pragmatic factors etc. We believe that eclectic methods are appropriate in the investigation of a heterogeneous field.

3.1.3 **Verb Classes and Types of Participants**

When choosing criteria appropriate for description of the predicate characteristics relevant in the reference interpretation, we follow some lines proposed by Fillmore, Halliday and Foley & Van Valin. The common point in their research is that they consider predicate as a nucleus of a clause, that is as an element which determines the internal structure of the clause syntactically (the number of necessary complements) and semantically (participant roles). Although these two aspects seem inseparable, in traditional systems of verb classification a distinction was often drawn between the two criteria of description:

1. semantic characteristics of a predicate, i.e. type of action/state/process described by the verb;

2. number and type of arguments/participants involved in an action or state described by the verb.

The separate consideration of these two aspects of the verb semantics may have been motivated by discrepancies between semantics of the predicate and the syntactic structure of a clause. It resulted in systems of verb classification based on either purely syntactic or purely semantic grounds.

A purely syntactic account of the German verb is presented by e.g. Helbig & Buscha [1974] who classify verbs according to the following criteria:

1. relations within the predicate (*Verhältnis im Prädikat*): main and auxiliary verbs;

2. relation to the subject (*Verhältnis zum Subjekt*): personal and impersonal verbs;

3. relation to the object(s) (*Verhältnis zum Objekt*): intransitive, transitive, ditransitive verbs;

4. relation to the subject and object (*Verhältnis zum Subjekt und Objekt*): reflexive and reciprocal verbs.

The semantic characteristics of the verbs and their arguments are given in the section on the semantically motivated syntactic constraints (e.g. formation of the *Vorgangs-* and *Zustandspassiv*). As a general type of verb classification, Helbig & Buscha give only an analysis of different *Aktionsarten*, i.e. types of action/process in respect to the time factor.

The new edition of the *Duden Grammatik* [1984] notes in the section on the subdivision of the verb class, that with respect to their meaning verbs can be classified as describing actions, processes or states (p.92). These semantic classes are vaguely linked with the number of participants. Verbs denoting an action usually involve two participants, while those denoting a process may involve one or two participating entities. Verbs of the third type, i.e. those denoting a state, may again involve one or two participants. Both the process and the state denoting verbs often require prepositional complements with local meaning. This approach ties up the semantic interpretation of the verb with the syntactic shape of a clause and, more specifically, with the grammatical function of subject. The type of subject's involvement determines the semantic class of a verb. This does not give much insight into the nature of the relationship between syntax and semantics, since the basic meaning associated with the verb (i.e. verb type) does not change drastically even if the grammatical function assignment changes. We believe that it is more appropriate to subdivide German verbs into semantic classes either without any reference to the grammatical functions of their inherent arguments or with a secondary indication of possible grammatical function assignments. Consequently, we are interested in systems of classifying the inherent participants parallel to the semantic verb classification.

In the preceding subsection we introduced some basic concepts of Fillmore's Case Grammar. Taking a set of semantic cases as linguistic

primitives allows us to classify verbs in a new way. Verbs may have the same set of cases associated with them (that is the same *case frame*) independently of their syntactic properties. This is because the structure of a basic proposition (defined as "a tenseless set of relationships involving verbs and nouns", Fillmore [1968a], p.23) does not have any *subject* or *object* labels on the nominal arguments. Consequently, subject loses its special position, its function comes from the surface syntax and is irrelevant for the basic semantic description of a predicate.

The classification of verbs according to their case frames is methodologically similar to the classification with respect to the subcategorization frames in phrase structure grammars. (We ignore here the different status of the subject NP in both models. Subcategorization works locally and applies only to the domain of the VP. Since subject is not dominated by the VP node, it does not belong to the subcategorization frame. A justification for excluding the subject NP from the subcategorization analysis was that the existence of a subject may be assumed and is always predictable, i.e. all verbs have subjects. This approach clearly ignores the distinction between personal and impersonal verbs, which apparently lack subjects. It also ignores the fact that some languages may have the subject incorporated in the finite verb form.) Despite this methodological similarity, the resulting classification of verbs is different. Subcategorization merely lists the syntactic environment of a verb and assigns the same syntactic description to structures with different meanings. It captures regularities in syntax. Case frames list semantic relations associated with a verb, its semantic environment, and the same set of semantic relations may be associated with syntactically different structures.

The concept of semantic cases was further developed by other authors. Foley & Van Valin [1984], representing the functional orientation in linguistics, propose a classification of verbs based on logical structures and corresponding semantic relations. Semantic roles used in their classification are: agent, effector, patient, theme and locative. Foley & Van Valin adopt a system of lexical decomposition of predicates and distinguish between a class of state verbs and a class of activity verbs, further subdivided according to some additional criteria. Activity verbs, e.g. are divided into those expressing potentially controllable actions and those expressing a motion. The potentially controllable actions are then subdivided into:

a. controlled actions - the logical form of the verb is DO (x('predicate'(y)) with x being an agent, acting in a volitional way, and y a patient;

b. uncontrolled actions, having the logical form x('predicate'(y)), with x being an effector and y being a patient. (p.53)

Verbs of motion involve one entity which is the theme and possibly a locative.

Having presented this detailed set of semantic relations associated with particular verbs, the authors introduce two more general and abstract notions - the ACTOR and the UNDERGOER. These two terms are defined as follows: the actor is "the argument of a predicate which expresses the participant which performs, effects, instigates or controls the situation denoted by the verb", while the undergoer is "the argument which expresses the participant which does not perform, initiate, or control any situation but rather is affected by it in some way" (p.29). The notions of actor and undergoer cannot be identified either with grammatical functions (subject may be either actor or undergoer) or with semantic case roles. However, they have "both semantic and syntactic significance" since they "constitute an interface between syntactic relations ... and semantic relations" (p.32). Foley & Van Valin further propose a hierarchy of actors-undergoers, associating these notions with the previously introduced semantic relations. The primary choice for an actor is agent, the primary choice for an undergoer is patient. Thus, an active clause with a transitive verb is a prototypical realization of these categories. The semantic relations of effector, locative and theme fall between them.

The concept of a hierarchy of actors-undergoers is modified and further developed in the following section. Here, we comment on yet another complex approach to the verb classification introduced in the late sixties by Halliday.

Halliday (first published in Kress (ed.)[1976]) uses the term *process* in a very broad sense to cover "all phenomena to which a specification of time may be attached - in English, anything that can be expressed by a verb : event, whether physical or not, state or relation" (p.158). He further distinguishes between different types of process and brings into consideration the number of participants that are "inherently

associated" with them (ibid.).

For modern English Halliday distinguishes three main types of processes: ACTION, MENTAL PROCESS and RELATION. For the verbs expressing the action type of process, ACTOR is the inherent participant in the predicate-argument structure. Action verbs may be involved in different syntactic constructions, which Halliday refers to as:

operative	ACTOR = subject + another participant;
middle	ACTOR = subject no other participants;
receptive	no ACTOR or ACTOR in adjunct position.

Operative and middle clauses correspond to the active voice, receptive clauses correspond to either passive or active voice. For action verbs, the actor is clearly the first choice for a subject position. The other participant of an operative clause, referred to as a GOAL, may, but does not always have to, be expressed. Whether its existence is presupposed by the speaker and whether it is to be inferred by the hearer depends on the idiosyncratic properties of the use of a particular verb, as well as on the situational context. Last but not least, it depends on the syntactic construction within which it occurs.

Mental process clauses involve at least two participating entities: "a human, or at any rate animate, being whose consciousness - feeling, perception etc. - is involved, and a phenomenon - object quality, event etc. - which impinges on it" (pp.165-166). The first of these is called PROCESSOR, the second the PHENOMENON.

Relational clauses are clauses "in which the 'process' takes the form of a relation between two participating entities, or between one participating entity and an attribute" (p.167). Halliday distinguishes between the attributive clauses (with an ATTRIBUTE and ATTRIBUEND) and equative clauses (with an IDENTIFIED and IDENTIFIER).

Halliday's classification systematically brings together the semantics of a predicate and types of inherent participants. In this thesis, we take a similar approach and analyse the discourse data following some lines proposed by Halliday. A system of verb classification adopted

for the purpose of this research is presented in Section 4.2. In the following section of this chapter we define the concept of *predicate frame*, further used for modelling the interpretation of reference.

3.2 Concept and Structure of Predicate Frame

3.2.1 Definition of Predicate Frame

In this thesis the concept of *frame* is applied as an explanatory device for the interpretation of referring expressions when there is no simple correspondence between the syntax and semantics of a sentence. We regard the *predicate frame* as equivalent to a general form of lexical entry for verbs. This is similar to the classic definition of frame (given in Minsky [1975] p.212) as "a data-structure for representing a stereotypical situation". If the notion of 'situation' is interpreted in a narrow sense, as 'what a verb is used for', then our use of the concept of frame conforms to this elementary definition.

A predicate frame (PF) as a structure for representing data necessary to describe a 'situation' is a notion potentially compatible with a variety of linguistic models. It is most readily applicable to the predicate calculus approach as a convenient way of describing predicate-argument structure. The basic predicate-argument network of relations may be 'spanned over the frame' and given an internal structure and operational form.

In a PF, the arguments of the predicate are represented as "'slots' that must be filled by specific instances of data" (Minsky [1975] p.212) and may have specified conditions which their assignments must meet. The number of *slots* in a particular PF is determined by the valency of a predicate. The argument slots have their assignments specified by features of the prototypical participants associated with those slots in natural usage. These features comprise the semantic requirements on arguments as they are specified e.g. by selectional restrictions in a standard phrase structure grammar, including the argument taking subject position (for examples see Subsection 3.2.3). The specification contains some extra information concerning the syntactic functions the argument can have and the principles of semantic and pragmatic interpretation of these functions. Rosenberg [1980] p.97, writing about frame-based text processing by computer, uses some extra features on frame slots - *facets*, and distinguishes between the following five facet types:

the $Value facet - contains the slot value;
the $Default facet - specifies a default value for that slot;
the $Require facet - specifies requirements which any value for that slot must meet;
the $To-Add facet - specifies procedures which must be run to compute a value for that slot;
the $If-Removed facet - specifies procedures which must be run if the slot value is to be removed.

Rosenberg's parsing model is an implementation of Goldstein and Roberts' [1977] frame representation language (FRL-Ø) which was based on 'deep case frames'. Deep case frames were defined in terms of the selectional restrictions and contained information on further frames that could be associated with the frame considered. The 'facets' associated with particular 'slots' in a 'deep case frame' contained the 'procedural knowledge' about those slots (on distinction between declarative and procedural knowledge cf. e.g. Bobrow and Winograd [1977]). Rosenberg's model described text processing at discourse level and the 'facets' on the frame slots referred to the principles of linking together text units. Our PF model employs the conceptual solution of facets with procedural knowledge for a slightly different purpose. The conditional form of facets (i.e. their "If-Then" structure) gives options for procedures that are to be executed if certain conditions are met. We may use facets with 'procedural knowledge' to operate on syntactic categories. We come back to this question and discuss it in more detail in Section 3.2.2.

One of the essential elements of the frame in Artificial Intelligence is the concept of *default value*, "a value which is taken to be the slot filler in the absence of explicit information to the contrary" (Hayes [1980] p.54). One remark is necessary at this point. When writing on default values and the model's expectations arising from the knowledge of frame defaults, many authors seem to imply (or indeed do imply) the psychological relevance of frame models. We must, therefore, note here that no claims about the psychological validity or adequacy of our PF model frame are intended.

Referring to the question of frame storage in long-term memory, Minsky [1975] p.228 writes:

> "Frames are probably never stored in long-term memory with unassigned terminal values. Instead, what really happens is that frames are stored with weakly-bound default assignments at every terminal!"

The *default* values associated with slots may be represented as a number of semantic (declarative in form and function) and syntactic (procedural) features referring to a *prototypical argument* or prototypical filler, which is instantiated if there is no specified slot value to take its place. In defining the *prototype* for an argument slot we take the point made, e.g., in Bobrow and Winograd [1977], who emphasized the importance of describing an object by comparing it to another object described in the memory. The object which is used as a basis for comparison, called the *prototype*, is not necessarily a specific individual but "a stereotypical individual which represents the 'typical' member of a class" and whose description "combines the 'default' knowledge applied to members of the class in the absence of specific information" (Bobrow and Winograd [1977] p.6). The default assignments, i.e. the prototypical slot values, therefore determine in a natural way the model's 'expectations' and are the basis for the mechanism of drawing inferences in order to fill in the missing information. The importance of people's ability to recognize "implicit causalities" and to infer missing bits of information have been pointed out by Lehnert [1980], who investigated the role of 'scripts' (situational frames) in human understanding and noted:

> "People are so adept at filling in missing information, that they often cannot remember what they were explicitly told and what they inferred." (pp. 81-82)

A *predicate frame* is a structure consisting of nodes (i.e. argument slots with their specifications) and relations. The lexical predicate is its *label*, and each time the 'label' is used, this instantiates a new predicate frame. When a new frame is instantiated it is a *copy* of a *basic PF* associated with a particular 'label'. If an argument value matching the slot entrance conditions is explicitly given and specified, it fills in the slot. If there is no specified value for a particular frame slot that must be filled (i.e. is required by the obligatory valency of the predicate) then the slot in the copy *inherits* the set of default values from the basic PF. Each time new data is added to the slot values, a new copy of the frame is made, where some slots have their values changed while some simply inherit values from the previous version of the PF. (On the mechanism of inheritance cf. e.g. Bobrow

and Winograd [1977], Goldstein and Roberts [1977] or Rosenberg [1980].) Because of the procedure of inheritance, each frame has a slot which specifies what basic PF the current PF is copied from. In the literature this slot is called AKO (A Kind Of) slot.

Information specified on argument slots of a PF is contained in:

a. semantic features with the value of a prototypical assignment (default value of the slot);
b. facets with procedural knowledge associated with argument slots (options for grammatical function assignments);
c. AKO-slot pointing to the basic PF.

The semantic information in the PF is discussed in Subsection 3.2.3. The facets operating on syntactic and pragmatic information are further discussed in 3.2.2 and 3.2.4. In Subsection 3.2.5 the relationship between the syntactic, semantic and pragmatic aspects of the interpretation of referring expressions is discussed and examples are given.

3.2.2 **Semantic Component of PF**

In the following two subsections we discuss the semantic, syntactic and pragmatic information contained in the 'features' and 'facets' of the predicate frame. We begin this discussion with the semantic component of the PF because of its primary importance for the entire structure of PFs.

According to the 'frame' definition (cf. Subsection 3.2.1), the number of frame slots (i.e. the number of argument positions in the verb valency) corresponds to the number of necessary elements in a stereotypical situation described by a given predicate. Thus, the arguments evoked by any use of the predicate correspond to the entities naturally participating in an event. We refer to them using the terms *inherent arguments* of a PF and *inherent participants* in an event respectively. Apart from the inherent arguments, predicates are normally open to all sorts of modification and, consequently, may be accompanied by various modifying elements such as expressions of time, location or manner. In our discussion we concentrate on the analysis of inherent arguments and their syntactic representation, and consider only those modal expressions that either have obligatory complement status (i.e. that are required by the valency of the predicate) or have a reference-supporting

function (discussed in Section 4.4).

First we introduce the terminology and notation used throughout this chapter.

Let V denote the set of all verbs in the language $\mathfrak{L}$. Then, we define valency as a function that takes as its arguments the elements from V and as its values natural numbers. We denote this function Val. Thus

$$V \ni v \xrightarrow{Val} Val(v) \in N \equiv \{0,1,2,\ldots n\}.$$

Remark. Let us note here that taking this approach we consider verbs that have two (or more) different valencies as two (or more) separate verbs. The status of facultative verb complements is further discussed in Section 3.3.

We distinguish two prototypical participant roles, Agent and Target, represented as <AGENT>, <TARGET>. The arguments of a verb may take either of them as their prototypical value, or may be specified as neither of them, i.e. take the value <OTHER>. We denote the set of the feature values by C,

$$C = \{ \text{<AGENT>}, \text{<TARGET>}, \text{<OTHER>}\}.$$

We define the predicate frame PF_k of the k-valent verb v as a (vector) function

$$V \ni v \xrightarrow{PF_k} PF_k(v) \in C^k, \text{ where } k = Val(v)$$

and where C^k denotes a Cartesian product of the set of features C. For instance

$$\begin{aligned} C^2 = \{&(\text{<AGENT>}, \text{<AGENT>}), (\text{<AGENT>}, \text{<TARGET>}), (\text{<AGENT>}, \text{<OTHER>}),\\ &(\text{<TARGET>}, \text{<AGENT>}), (\text{<TARGET>}, \text{<TARGET>}), (\text{<TARGET>}, \text{<OTHER>}),\\ &(\text{<OTHER>}, \text{<AGENT>}), (\text{<OTHER>}, \text{<TARGET>}), (\text{<OTHER>}, \text{<OTHER>})\}. \end{aligned}$$

By C^0 we denote the empty set $\emptyset$.

The features <AGENT> and <TARGET> represent the two extreme opposite types of argument involvement in an action. They are semantically complex, i.e. they in turn have some prototypical properties associated with them. <AGENT> prototypically implies a volitional and goal-oriented instigator of the action described by the verb, and these features are commonly treated as characteristics of human activities.

Thus, the feature <AGENT> associated with an inherent argument suggests humans as prototypical instigators of an action. Being a <TARGET> of an action, on the other hand, suggests a rather passive involvement of an argument, i.e. does not imply volitionality and, consequently, is not prototypically associated with humans. The relative position of <AGENT> and <TARGET> in the animacy hierarchy is shown below:

<TARGET> ∋ Inanimate ∋ Animate ∋ Human ∋ <AGENT>

where ∋ denotes the animacy hierarchy partial ordering. The scale of the prototypical involvement in an action naturally corresponds to a scale of prototypical participant roles. We have distinguished only the extreme points of that scale, i.e. a prototypical AGENT and a prototypical TARGET of an action, and we deliberately do not state the prototypical conditions on other participant roles, such as INSTRUMENTAL or EXPERIENCER. Arguments of a predicate, when defined in terms of prototypical participants, are functions of the lexical meaning associated with that predicate by the language users; they "derive from the semantic structure of predicates themselves" (Foley & Van Valin [1984], p.27).

The prototypical argument assignments are conceptually related to the deep cases as employed in Fillmorean case grammar (and to primitive notions of participants in Burke [1969]). Fillmore [1968] defined his cases as sets of "universal, presumably innate, concepts which identify certain types of judgements human beings are capable of making about events that are going on around them, judgements about such matters as who did it, who it happened to, and what got changed" (p.24).

Despite the formal similarities between the deep case frame in the early version of Fillmore's case grammar and the predicate frame in our model, the two concepts are basically different.

Fillmore's grammar assigned semantic cases to the lexically specified objects. Thus, the deep case assignment depended on, or was even determined by, the lexical characteristics of the argument. For example, whether an NP was assigned 'Agentive' or 'Instrumental' case was mainly determined by whether it denoted an animate or inanimate object. Consequently, verbs could have different case frames associated with them, according to the variety of possible lexical fillers of the argument slots. At the same time, the great diversity of the possible lexical fillers for the same argument slot, combined with a wide range

of the possible semantic verb types, naturally resulted in a relatively big inventory of cases. Even this big inventory, however, was not sufficient to provide a full description for all sentences of a natural language, and this despite the fact that some of the Fillmorean cases (e.g. the 'objective') had very broad and vague definitions. What Fillmore's case grammar lacked was the notion of a stereotype role-player, i.e. the notion of a prototype.

In our model, the prototypical roles are permanently associated with slots, and the lexical assignments may only modify the prototypical slot value. Thus, the semantic interpretation of an argument position filled by a lexical element is a function of:

1. the prototypical value assigned to the PF slot, and
2. the semantic features associated with the lexical filler for that slot,

and may differ from the prototypical value assigned at the PF-level. At that level we operate with a simple distinction: <AGENT>, <TARGET>, <OTHER>. Agents and Targets are the only participants whose roles derive from the semantic structure of predicates themselves, as Foley & Van Valin [1984] put it. (This is true for the prototypically action verbs. We discuss other semantic verb types and the feature <OTHER> towards the end of this subsection.) The part of the scale between the two extremes may be seen as a passage from prototypical to 'peripheral' Agents (non-volitional humans, animate objects, force, inanimate, objects, etc.), and 'very bad' Agents may naturally be seen as 'reasonably good Targets'. (The concept of a continuum of participant roles has been proposed by Schlesinger [1979] who argued for this approach to the Instrumental-Comitative distinction.) Although Agent and Target are two extremes, it is these two participant roles that appear to be most frequent in the language use. It is also striking that they may be associated with the same referent, even within one discourse unit, e.g. within one clause. The most common instance of the double role of one participant are some reflexive constructions where the same participant is both the source (Agent) and the goal (Target) of an action. We discuss reflexive constructions in more detail in Section 3.3 and in Chapter 5, where the use of the impersonal pseudo-reflexive constructions is illustrated with examples from scientific discourse.

The prototypical Agents and Targets account for the representation of prototypical actions. These, however, constitute only one fragment of the system of verbal predication in general. In Fillmore's model, 'deep cases' were designed to cover the entire network of semantic relations holding between predicates and their arguments. As pointed out above, Fillmore's case system was built up on elements derived from two different sources. These were: the verb semantics, represented as abstract human knowledge of the situational patterns (type and number of participants) and semantics of the actual lexical items that co-occur with particular predicates in language use. These two sources correspond to two separate levels of language description - the level of actual, lexically filled clauses, and the level of a more abstract semantic representation of the content of those clauses. We shall try to avoid defining concepts from one level of description in terms specific for the other. Therefore, our level of semantic representation corresponding to the basic PF-structure contains exclusively information about the prototypical argument assignments, i.e. we distinguish only between prototypical Agents and Targets at that stage. If the notion of a prototype is to be of any importance, we should avoid multiple 'prototypes'.

Instead of multiplying primitive notions in the semantic representation and introducing additional roles into the basic PF we leave this further differentiation of participant roles to the level where the slots in a copy of the basic PF are filled with the lexical material. It is here that the prototypical features are confronted with those of the lexical items. The slot inherits its basic role assignment (i.e. it remains either more Agent- or more Target-like), but the features of the lexical item may override features specified as a slot default value. We may now define other common participant roles as resulting from certain combinations of the prototypical feature assignments and actual features of lexical items that do not match the slot defaults. Thus, slots with the feature <AGENT> as an inherent value, filled in by lexical items denoting inanimate, concrete objects, may be interpreted (if the lexical meaning of the verb allows for that interpretation) as Instruments. If the lexical item filling in the <AGENT> position has the feature indicating the location, it may receive an interpretation as Source. The animate, especially human, Targets, on the other hand, may receive interpretation as Experiencers, and if they indicate location, they may be interpreted as Goals, according to the position in the PF, i.e.

according to the verb semantics.

The feature <OTHER> is assigned to the argument slots that permit neither Agentive nor Target interpretation. This is the case for PFs with monovalent verbs; i.e. verbs involving only one participant. This is also the case for relational predicates, especially those involving the verb BE. (For a semantic description of elementary sentences with the verb BE cf. Matheson Styan [1987].) A more detailed analysis of verbs taking arguments with the feature <OTHER> as used in mathematical discourse is presented in Chapter 5.1.3.

3.2.3 **Syntactic Component of PF**

The PF of the verb v is an ordered set of prototypical features for argument slots whose number equals the verb valency k. (Actually the number of PF slots is K+1, since we have an additional slot, the AKO-slot, containing the reference to the basic PF.) The ordering of the PF argument slots is implied by the language system itself and can be arrived at by morphological and syntactic tests. In some languages, e.g. those from the Indo-European family, syntax reflects the intrinsic ordering of arguments by assigning the same grammatical functions to the same participant roles (although this cannot be considered as a rule). In German, for instance, semantic 1st participants are commonly assigned the subject position in the morphologically simpler (synthetic verb form in the Present Tense) type of construction (i.e. in the active). The subject position is therefore syntactically neutral and pragmatically unmarked for the 1st argument. Each PF has its intrinsic argument ordering and the neutral syntactic function assignment. If an argument is to be moved out of its neutral position, e.g. in a passive construction, the conditions of such movement are specified in the 'If-Removed' facets.

The fact that an argument may be moved out of its neutral syntactic position is marked by the presence of the 'If-Removed' facet associated with its slot. The information contained in that facet specifies other syntactic positions that can be taken by the argument and states the principles of the semantic interpretation of that movement (no transformational sense is implied). These rules of interpretation comprise the pragmatic relevance of the sentence topology. 'If-Removed' facets account specifically for those cases when an argument slot does not have its value lexically specified, i.e. its filler is missing in

the actual clause. The patterns of interpretation of the missing arguments, encoded in the PF, allow therefore for interpretation of the impersonal constructions. We describe these patterns for German impersonal constructions in Chapter 4.

For languages such as German or English, which require the syntactic subject position to be filled, it is necessary to describe the conditions and constraints on subject demotion or other arguments promotion. An argument may be promoted to a 'higher' position in the syntactic hierarchy (which usually corresponds to the ordering of the arguments in the PF) if it has the 'If-Promoted' facet associated with its slot. This is for instance the case for the 2nd argument of predicates describing prototypical actions, and generally for 'transitive' verbs. The 'If-Promoted' facet specifies other syntactic positions that the argument may be moved to and the conditions of such promotion (e.g. the verb-marking which indicates a 'non-neutral' form - in German it is the passive- or reflexive-inflection). Since the primary reason for the argument demotion/promotion is pragmatic, the pragmatic conditions must also be specified to allow for the interpretation of the topological and syntactic changes. The pragmatic information, however, cannot be contained in the PF since it is provided only by the context of the speech act. The principles of pragmatic interpretation may be represented as a set of language specific rules for expressing the pragmatic relations (focussing, theme-rheme distinction etc.) by means of syntax, morphology, word order, intonation, etc. In Chapter 4 we describe how in German scientific discourse pragmatic information may be linked with the PF information.

Below, we give the structure of a basic PF for the verb *zeigen* ('to show'), when no lexical information is added.

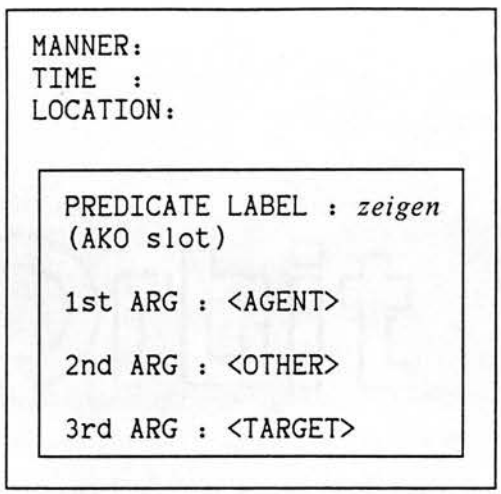

Figure 1. Basic PF for the verb *zeigen* with prototypical semantic feature specification

If no pragmatic information is supplied by the context, a neutral grammatical function assignment takes place, i.e. 1st argument is taken as subject. A different choice is made if, for pragmatic reasons, the 'If-Removed' facet is activated, i.e. when the reference to the 1st participant is to be avoided. This question is discussed in more detail in Chapter 4.

3.3 Relations between Semantics and Syntax in the PF-Model

3.3.1 Predictability of Inherent Arguments

In the previous sections we have defined the concept of predicate frame and described PF-structure, indicating the three aspects or types of information to be represented in or linked with a PF - the semantic, syntactic and pragmatic information. Let us now discuss, in terms of the PF-model, the relations between syntax, semantics and pragmatics of some German constructions.

Being implied by the verb semantics, the inherent arguments of a predicate are *predictable*. If they are not explicitly specified in a particular sentence, they may be 'reconstructed' either by reference to hearer's knowledge (general knowledge or knowledge of a particular situational context) or by reference to the frame of the lexical predicate (i.e. by the reference to the knowledge of the language system). Let us illustrate this point with an example. The German verb *lesen* ('to read') requires an entity who does the reading and something that can be read. We may infer the existence of the latter in (1b and c):

(1) a. Hans liest eine Zeitung 'Hans is reading a paper'
b. Hans liest 'Hans is reading'
c. Hans liest viel 'Hans reads a lot' .

In addition, the existence of a reader can be inferred in (1d):

(1) d. Zu dieser Zeit wurde viel gelesen
'at that time people read a lot' .

The PF for *lesen* needs to have two argument slots filled in. When interpreting (1b and d), our model makes a frame copy with *default* values for the 2nd or for the 1st argument slot respectively.

One might suggest that (1b) does not describe the reading of a particular book or paper but rather reading as an activity at a particular time, and (1c) reading in general, as a hobby or Hans' favourite pastime. In fact (1c) may be interpreted as a statement of Hans' good knowledge of literature in general or on a particular subject. On the other hand, the existence of the inherent 2nd argument may be confirmed by the possibility of asking a WH-question about that

argument, as in (2):

(2) a : Hans liest; Du darfst ihn nicht stören!
'Hans is reading; you must not disturb him!'
b : *Was* liest er denn?
'what is he reading then?' .

B's question in (2) shows that the existence of the 2nd argument may be inferred, even if one interprets (1b) or (2a) as used to refer to reading as a pastime. Although that argument may be left lexically unspecified it is inferrable as a sort of *cognate object* of the predicate.

Inherent arguments with the same syntactic status (e.g. Accusative-objects) do not necessarily behave in a syntactically uniform way. Their semantic value may influence their syntactic properties. The 2nd argument of the verb *lesen* is highly predictable since it has a considerably narrow meaning. 'Something to read' consists of a set of books, papers, leaflets etc., and each specific context narrows the acceptable interpretation. Metaphorically, *lesen* may also be used with abstract objects as in (3):

(3) Er konnte in ihren Augen die ganze Wahrheit lesen
'he could read the whole truth in her eyes'

or, apparently, without any object, as in (4):

(4) Er konnte in ihren Augen wie in einem Buch lesen
'he could read in her eyes as in a book' .

Then, however, it is either impossible to omit the object (since it is no longer predictable due to the fact that its semantics violates feature specifications on the frame slot) or the metaphorical character of the utterance is made explicit, e.g. by means of comparison, as in (4).

The syntactically similar (i.e. followed by an Accusative NP) verb *machen* ('to do'/'to make') does not behave in the same manner as *lesen*. Its 2nd argument, 'something to be done', has a very broad meaning, which can hardly be predicted. Although its existence is predicted by the PF, it can hardly be omitted since it is in most cases the rhematic, new and relevant part of a sentence, as in (5):

(5) Frau Claire Zachanassian bietet eine Milliarde, wenn ihr *das Unrecht wieder gut macht*, das Frau Zachanassian in Güllen angetan wurde
'Mrs Claire Zachanassian is offering a milliard if you put right the wrong that was done her in Güllen'
Dürrenmatt, *Der Besuch der alten Dame*

or it is in fact part of the predicate, as in the so called *Streckform* of the verb in (6):

(6) Ihr scheint *eure Erfahrung* mit der Polizei *gemacht zu haben*
'you seem to have had some experience of the police'.
Dürrenmatt, *Der Besuch der alten Dame*

The 2nd argument of *machen* may, however, still be promoted to the thematic subject position and then left out as in (7a) or (7b):

(7) a. - Erinnert sich jemand an ein Gebäude, das ihr Vater errichtete? *Würde sich gut* in der Rede *machen*
'does anybody remember a building that her father erected? it would fit well in the speech'

b. - Sofort! Sofort! Der Arzt besitzt ein Automobil...
- *Wird gemacht*, Herr Bürgermeister. Den Wagen schaffe ich behördlich zur Stelle
'immediately! doctor has a car...'
'it will be done, your Honour. I'll have the car brought here officially'.
Dürrenmatt, *Der Besuch der alten Dame*

The promotion to the subject position is accompanied by the rearrangement of the syntactic structure, i.e. it requires either passivisation or reflexivisation of the sentence. The subject NP, even if its semantics has already been established, i.e. if the thing to be done has been mentioned in the previous discourse, may be left out syntactically only in colloquial (spoken or written down) German, not in standard written German.

The intransitive (as illustrated in (8)) or reflexive (as illustrated in (9)) use of the verb *machen* does not correspond to the same PF as its transitive use.

(8) Mach doch!
'get a move on!'

(9) Wann machst du dich endlich an die Arbeit?
'when will you get started to your work?'.

Structures with *machen* used intransitively cannot be interpreted as direct object ellipsis, and examples with the reflexive *machen* cannot have the reflexive pronoun *sich* translated as a proper 2nd argument (e.g. since *sich* does not allow for passivisation). These three uses of *machen* represent different degrees of transitivity. The intransitive and reflexive *machen* would, therefore, require separate lexical entries. The question, whether the PF's for $machen_{intr}$ and $machen_{reflex}$ are derived from the basic PF for $machen_{trans}$ cannot be answered without diachronic evidence. This question, however, refers to the organization of the lexicon and is not of major importance for the purpose of the present discussion.

The relationship between the semantic and syntactic representation of a predicate-argument structure may be seen as a one-to-one isomorphic mapping between these two levels when all inherent arguments from the semantic representation have their syntactic counterparts, and all constituents of a sentence represent inherent arguments (facultative or obligatory), i.e. when there are no syntactically *unemployed* or semantically empty constituents.

This ideal mapping is not the only one possible. Modern German shows another type of relation. Following the distinction suggested in the literature (cf. Höhle [1978]), we may talk about constituents without arguments and arguments without constituents. We shall discuss these two cases in more detail below.

3.3.2 Constituents without Arguments

The standard example of 'constituents without arguments' are some reflexive constructions. Reflexivity is a characteristic of a class of verbs, such that the subject and the object of a verb are referentially identical (i.e. co-referential) and the action described by a verb is carried from the subject <AGENT> to the object <TARGET>. The reflexive relationship may be, but does not have to be, explicit. English, for instance, distinguishes between explicitly (i.e. mirrored by syntax) and covertly reflexive constructions, as illustrated by (10a) and (10b)

respectively:

(10) a. John didn't wash himself
b. John didn't shave this morning .

Examples in (10) are *properly* reflexive, since John is physically agent and patient of washing. This fact is confirmed by the syntax, since *himself* in (10a) may be substituted by another NP as e.g. in (11a):

(11) a. John didn't wash the car

and the empty argument slot in (10b) may be filled by an NP not co-referential with the subject, as e.g. in (11b):

(11) b. John didn't shave the client.

The verb *behave* is also either explicitly or implicitly reflexive. However, if it occurs with a reflexive pronoun, that pronoun cannot be substituted by anything else.

(12) Can't you make your little boy behave (himself)?
*herself, *yourself, *him... etc.

We shall use the term *improper reflexive* to denote verbs with similar properties to *behave.*

The German language has many reflexive verbs (both *proper* and *improper*), but in most cases the reflexive pronoun *sich* (*mich*, *dich* etc. respectively) is obligatory and cannot be left out.

The following questions arise:

1. does the reflexive pronoun *sich* correspond to the syntactic object?
2. does the constituent represented by *sich* correspond to an argument in the semantic structure?

We shall try to answer the above questions for both types of German reflexive verbs.

It must be noted here that a different terminology is used by e.g. Helbig and Buscha [1974] who also distinguish between *echt* (i.e. *proper*) and *unecht* (i.e. *improper*) reflexive verbs. *Echt* reflexive are for them those verbs where no substitution for the reflexive pronoun is possible.

They add, however:

> "Im semantischen Sinne liegt nur bei Gruppe 2 (unechte reflexive Verben) eine echte reflexive Beziehung vor, da nur bei diesen Verben von einem Subjekt und Objekt überhaupt gesprochen werden kann." (p.66)

The definition of reflexivisation adopted in this thesis and given at the beginning of subsection 3.3.2, presupposes that an agent carries out an action of which he himself is the goal or object (target). For most of the *improperly* reflexive verbs, we can hardly talk of an action. The verbs *sich schämen* ('to be ashamed'), *sich benehmen* ('to behave'), *sich verlieben* ('to fall in love'), *sich befinden* ('to find oneself') etc., do not describe any action in the prototypical physical sense and it would be rather peculiar to distinguish between the two different roles of the subject involved; that of an Agent and that of a Target.

For those verbs, the reflexive pronoun does not behave like a proper object. We cannot e.g. ask any WH-questions about it:

(13) **Wen* schämst du?

If it is impossible to ask questions about this particular constituent, we may assume that it does not correspond to an argument of the semantic representation.

Some Polish reflexive verbs show similar syntactic properties. The syntactic and semantic 'emptiness' of reflexive pronouns is confirmed by the fact that the reflexive element *się* may be left out in constructions involving two reflexive verbs. The reason for this omission is primarily stylistic, but it is made possible by the lack of syntactic and semantic functions. Examples are given in (14):

(14) a. Postaraj się nie wstydzić
'Try-REFLEX-not-to be ashamed'
b. Postaraj się nauczyć tego
'Try-REFLEX-to learn-this'

where all verbs (i.e. *starać się* ('to try'), *wstydzić się* ('to be ashamed') and *uczyć się* ('to learn')) are reflexive, the first two are *improperly* reflexive, while the last one is *properly* reflexive (i.e. we may have it used transitively, although with a shift in the meaning - *uczyć się*$_{\text{reflex}}$ corresponds to English *learn*, *uczyć*$_{\text{trans}}$ to English *teach*; thus (14b) is ambiguous).

Some German verbs co-occur with pronouns having both functions (i.e. reflexive and transitive object) but it never happens in the same sentence (cf. the principle of coordination as stated e.g. in Gazdar et al. [1985]). The example in (15):

(15) *Ich fürchte *mich* und *ihn*

is ungrammatical since *ihn* has object status and the reflexive *mich* is syntactically *unemployed* (e.g. cannot be passivized).

There is yet another syntactic test of the object status of German reflexive pronouns. We may check how the participles derived from both types of reflexive verbs behave if they are used as attributes of their previous subjects (i.e. 1st arguments of their PF-s)

(16) a. der Junge wäscht sich
'the boy washes himself'
b. der gewaschene Junge
'the washed boy'
c. der sich waschende Junge
'the boy washing himself'

(17) a. der Junge benimmt sich gut
'the boy behaves himself well'
b.*der gut benommene Junge
'the well behaved boy'
c. der sich gut benehmende Junge
'the boy behaving himself well'.

The sentences in (16b) and (17b) suggest the reading to be *ge(-x-)t/en* by someone else, which in German is acceptable only for the properly reflexive verb in (16). (17b) is incorrect, since *der Junge* cannot be seen as a target of the action referred to by the use of the verb *sich benehmen*. Consequently, the subject and the reflexive pronoun *sich* in (17) are not co-referential. Some *improperly* reflexive verbs apparently differ from the pattern illustrated in (17), *sich verlieben*, e.g. allow for a construction corresponding to (17b) and illustrated in (18):

(18) a. der Junge verliebte sich
'the boy fell in love'
b. der verliebte Junge
'the boy in love'

c. der sich (oft) verliebende Junge
'the boy (often) falling in love'.

Helbig & Buscha [1974] and *Duden-Grammatik* [1984] refer to the construction in (18) as *Zustandsreflexiv*, distinguishing it from the proper *Zustandspassive*. This difference is due to the fact that *Zustandsreflexiv* has an active interpretation. The pronoun *sich* in (17) and (18) is only formally identical with the one used with reflexive verbs and may be treated as a part of the idiosyncratic verb morphology. As such it may be handled in the lexicon although it exhibits different properties than the verb inflection. (It is a separate element and has a changing position; it may be treated as a verb particle.) It cannot be properly handled by the syntax because it is a constituent without a corresponding argument.

We now consider another example of a non-isomorphic mapping between syntax and semantics. The difficulties in the syntactic and semantic description of German *es* have often been mentioned in discussions of impersonal verbs and constructions (cf. Subsection 1.3.2). Now, we analyse a different type of sentence with *es*. It is illustrated in (19):

(19) Es sei ABC ein Dreick mit der Eigenschaft...
'let ABC be a triangle with the property...' .

If we compare (19) and (20):

(20) a. ABC sei ein Dreick... 'let ABC be a triangle...'
b. ABC ist ein Dreick... 'ABC is a triangle...'

we may say that they all refer to the same basic fact (or to the same PF) and differ in modality and in rhetoric or expressive value. If they all have the same predicate-argument structure (i.e. PF), then the pronoun *es* in (19) is an extra element without argument status. As such, it does not have constituent status in the syntactic representation either. If we start our analysis from the syntactic representation, we should arrive at the same conclusion because we cannot assign to *es* any syntactic function. The NP *ABC* has a subject function and controls the verb agreement, which may be confirmed by (21):

(21) Es *seien* ABC und DEF Dreiecke...
'let ABC and DEF be triangles...'

where the verb necessarily shows agreement with the Plural subject. *Es* in (19) remains syntactically unemployed and vanishes if something else takes the sentence initial position. Schatte [1982] refers to this function of *es* as 'the sentence ordering function' and quotes such examples as *Es steht ein Baum im Odenwald* (cf. Subsection 1.3.2). The standard initial sentence of German fairy tales *Es war einmal...* has a similar structure.

The word order with an initial *es* permits everything that follows the thematic pronoun to be treated as new and relevant. While the examples with the non-syntactic *sich* may be described by means of morphology, it seems that the description of *es* in constructions such as (19) requires pragmatic explanation. The presence or absence of *es* influences and changes the functional sentence perspective, using the terminology of the Prague School. Thus, *es* in (19) has a discourse function. Syntactically, it is there only to give the finite verb the second position. The pragmatic function is to leave the thematic position semantically empty.

These two examples of a non-isomorphic mapping between the predicate-argument structure and the syntactic constituent structure (i.e. examples with improperly reflexive verbs and with pragmatically justified initial *es*) illustrate the case when the number of constituents is apparently bigger than the number of arguments in the predicate-argument structure. It is only 'apparently' bigger, because the syntactically unemployed *sich* and *es* do not have their own grammatical functions. This type of discrepancy between the syntax and semantics of a sentence does not pose any particular problems for the interpretation of reference.

3.3.3 **Arguments without Constituents**

Now we consider the case when the syntactic representation contains fewer constituents than the number of inherent arguments of the predicate-argument structure in the PF. We may generally distinguish between:

1. ellipses motivated by pragmatic and stylistic factors, and
2. omissions motivated by the rearrangement of the syntactic structure itself .

Ellipsis has been defined by many linguists in a relatively homogeneous

way. Let us recall some of the relevant definitions, starting with the one by Gotfried Herrmann, (after Lewandowski [1979]): "ellipsis est ommissio vocabuli, quod et si non dictum tamen cogitatur". Lewandowski [1979] defines ellipsis as "Kurzform der Parole", that is as:

> "Auslassung von Satzgliedern, Redeteilen, Morphemen, die durch Kontext and Situation (im engeren und weiteren Sinne) bedingt oder ermöglicht wird. ...Nicht-Besetzung von Leerstellen, Nicht-Realisierung der Fügepotenz in der Parole".

This definition introduces the notion of valency and we may interpret it in the following way: Only those elements of a syntactic structure may be elliptically omitted that are predictable from the specification of the predicate frame, and that, if made explicit, would function as *given* and *known*, i.e. non-rhematic.

An interesting type of ellipsis in German, is the omission of a finite auxiliary verb in the *Perfekt* and omission of the present participles *habend* and *seiend*, as illustrated in (22) and (23):

(22) a. Maria Magdalena, sag uns was du *gesehen*
'Maria Magdalena, tell us what you saw'

b. Auch wer zur Nacht *geweint*, der stimme froh mit ein
'also whoever has wept by night, joins happily in the singing'

from German Church songs

(23) Er stand vor der Tür, Koffer in jeder Hand
'he stood at the door, a case in each hand' .

(Note that (23) could also be interpreted as an apposition.)

It is interesting that the above examples are characteristic for two different registers of German. The type illustrated in (22) is typical for literary texts while the type illustrated in (23) occurs predominantly in colloquial German. *Duden Grammatik* [1984] explains (22) as the stylistically motivated omission of redundant auxiliary verbs. Accepting the stylistical explanation, we might add that the ellipsis is possible because the occurrence of the verb is predictable (inferrable) from the syntactic structure of the sentence (for the auxiliary verb in *Perfekt*) or from the semantics (for the participle in (23)). We may note that the omission of the participles *habend* and *seiend* in German resembles the present Tense constructions involving the

verb *to be* in Russian. The verb is omitted, and only the nominal arguments are expressed, e.g. subject and the predicative adjective. Russian equivalent of the verb *to have* is *to be* associated with two arguments: one expressing location and corresponding to the 1st argument of the English *to have* (however, expressed by a prepositional phrase i.e. not functioning as subject); the other corresponding to the 2nd argument of the English *to have* and functioning as subject. The verb form is omitted. An excellent discussion on the structure- and/or discourse-dependent character of elliptical expressions is presented in Cornish (1986).

An analogous elliptical omission of the auxiliary verb in the Past Tense (as in (22)) led to a major morphological change in the Polish system of Tenses (cf. 24).

(24) a. Ja to by*łam* (1st Pers., Sing., Fem., PAST) zrobi*ła*
(Sing., Fem., PAST)
'I have done it'
b. Ja to zrobi*łam* (1st Pers., Sing., Fem., PAST)
'I did it'
c. Zrobi*łam* to (1st Pers., Sing., Fem., PAST)
'(I) did it' .

The Polish past participle, however, showed the Gender and Number agreement with the subject, so that the auxiliary verb (after the participle also took the Person marking) became redundant and eventually vanished. Modern Polish does not use the analytical Past Tense except in literature. The Polish constructions with deictic pronouns of the 1st, 2nd (and sometimes 3rd) Person incorporated into the finite verb form cannot be treated as elliptical omissions either. This omission is motivated not only by the pragmatic redundancy (referents are inferrable from the context) but also by the morphological redundancy. The pronoun simply repeats the same information that is already encoded in the finite verb form. If it is used, then it is usually marked as emphatic or contrastive.

We restrict the use of the term *ellipsis* to the omissions that are motivated by communicative (i.e. stylistic and pragmatic) redundancy only. These cases are different from the omission of inherent arguments of a PF motivated by syntax, i.e. required, due to the rearrangement of the predicate-argument structure.

Syntactically motivated omission - usually of the 1st argument - takes place if the element omitted is either redundant or demoted from its syntactically neutral (prototypical in terms of the PF-model) position and syntactically unemployed.

An important difference between context motivated and syntactically motivated omission relates to the reconstruction of the missing elements. Pragmatically and contextually motivated ellipsis is revealed by knowledge of situation (in a broad sense, i.e. including the co-text and including the impact of the group specific rhetoric). Syntactically motivated omission, which may be illustrated by e.g. passive and impersonal constructions, is reconstructed by the knowledge of the syntactic and semantic system of a language. Thus, these two types of reconstruction present different levels of difficulty. Ellipsis, as context dependent (and in most cases supported by means of morphology and syntax - e.g. agreement), is easily revealed if in an appropriate context and, consequently, may be more readily used in colloquial spoken discourse (for analysis of situation-dependent ellipsis and anaphora cf. Hankamer & Sag [1976]). In a written, context-independent discourse, e.g. in mathematical texts, only a co-text dependent ellipsis is recoverable. On the other hand, the syntactically motivated omission, which involves reference to the predicate frames (i.e. to the syntactic and semantic representation) is frequently used in written and more sophisticated discourse, in general where extra time is allowed for text processing (cf. Chapter 2). Scientific discourse favours syntactically motivated omission, because it allows certain arguments to be left out without affecting the context-independent character of the discourse. This is why passive, subjectless or reflexive impersonal constructions are used in scientific texts more often than anywhere else. (For a comprehensive study of the 'situation-independent' texts cf. Meyer [1983].)

While both types of omission result in semantically, and consequently referentially, incomplete syntactic structures, elliptic sentences are often also syntactically defective and ungrammatical if analysed in isolation. The other type of omission yields grammatically correct and apparently complete sentences - this is why this type of construction (i.e. impersonalia) has often been analysed in isolation. The referential incompleteness of impersonal constructions is less obvious and often ignored. The PF-model offers a fairly simple descriptive mechanism to capture the relationship between the syntactic and semantic

representation in this case.

3.3.4 Indirect Reference

In the rest of this section we discuss how the PF-model interprets the German impersonal constructions in terms of *indirect reference*, and illustrate it with some examples.

If some of the necessary participants of an event, i.e. some arguments of a predicate frame, instantiated by the use of its *label*, remain unspecified, the model follows the instruction on the facets (cf. the 'If-Removed' facet in Section 3.2) that specify how the reference may be established. As described in Section 3.2, the PF contains the most expected semantic features of the prototypical participants. The prototypical assignments for argument slots are determined by the basic meaning the language user associates with a verb, and are completed or modified by the individual linguistic experience and by the context. Having assumed (cf. Chapter 2) that the Gricean principle of cooperation is valid in the restricted context of scientific communication, we take it for granted that the speaker can omit to specify a participant only if he believes that the audience is able to infer or interpret the missing element of the message on the basis of their own knowledge. This is in general true also for non-technical communication and, therefore, constructions as in (25):

(25) Es wurde getanzt 'there was dancing'

are used if the referent of the first argument slot can be successfully inferred from the context (e.g. *die Hochzeitsgäste*). If this is not the case, constructions as in (26) or (27) would be used instead:

(26) Die Hochzeitsgäste tanzten 'the wedding guests were dancing'
(27) Wärend der Hochzeit wurde getanzt
'during the wedding there was dancing' .

On the other hand, the sentences in (28) do not bring more information than (25):

(28) a. Die Leute tanzten 'people were dancing'
b. Man tanzte. 'they danced'

since the semantic feature +HUMAN is a default assignment for the 1st argument slot in the PF for *tanzen*.

The difference between (25) and (28) is that the sentences in (28) have the argument values explicitly specified, i.e. the argument slot is filled by a lexically non-empty elements which do not violate the prototypical feature specification. Therefore, there is no need to check the feature default specification on the frame slots in order to interpret the sentence. In (25), however, no argument value is provided and the model instantiates the frame with the argument default value for the missing participant.

If it is necessary to refer to the semantic features of an argument listed in the basic predicate frame in order to identify the referent of an expression (as it is the case for impersonal constructions), we consider that expression *indirectly referential*.

We may note here that a similar concept of reference as an intersentential link has been described by Rosenberg [1980], pp.99. Rosenberg distinguishes this type of reference, simple *frame reference* (called "reference using slots") from *paraphrase* ("frame reference by name") and from *contextual reference* ("frame reference by description"). He defines frame reference as "a form of reference which depends on the empty slots of a frame for effect" (ibid.). Frame reference is illustrated with the following example:

(29) a. John shot his wife
b. The gun was a forty-five caliber automatic ,

and Rosenberg comments that "the sentences can be linked through the realization that the action of the first sentence ('to shoot') has an unspecified instrument. The second sentence specifies this instrument" (ibid.). The concept of describing recognition processes in terms of a comparision to a stored stereotype is also present in Bobrow and Winograd [1977] and other AI works on natural language processing (cf. Schank & Nash-Webber (eds.) [1975], Metzing (ed.) [1980] etc., the most recent being the Proceedings of the 7th European Conference on AI [1986]).

The following chapter presents the data from German mathematical discourse that have been analysed and the methods used for their description. The mechanism of indirect reference retrieval is employed for the analysis of impersonal constructions in German scientific discourse.

CHAPTER 4

MECHANISM OF INDIRECT REFERENCE IN GERMAN MATHEMATICAL DISCOURSE

4.1 Research Materials and Methods

4.1.1 Introduction

In this chapter we use the predicate frame model, presented in the previous chapter, to describe a cross-discourse reference tracking mechanism. We begin by presenting (in Subsection 4.1.2) the data used for the purpose of this research. Then, (in Subsection 4.1.3) we give the criteria which were adopted for a formal description of the clause internal structure, i.e. for the analysis of the relations holding between a predicate, its inherent arguments and other elements of a clause. We further discuss (in Section 4.2) the system of verb classification based on discourse roles adopted in this thesis.

In the following sections we describe the mechanism of indirect reference in the restricted context of scientific communication. We discuss the use of indefinite and generalised pronouns, pronoun shift, and reference switching in the case of indefinite referring expressions. In Section 4.5 we comment on the use of direct reference in mathematical discourse. Finally, in Section 4.6, we indicate the results of a pilot count carried out on a small data sample.

4.1.2 Research Materials

The research on indirect self-reference of the author in scientific discourse presented in this thesis is based on two data sets from German mathematical discourse. The first corpus, which we shall further refer to as corpus A, consists of twelve papers on various mathematical topics. Six of the papers are recent. We have chosen most of the texts from mathematical journals, as opposed to e.g. monographs (or parts of monographs), because they represent a variety of different idiolects. This, consequently, diminishes the danger of domination of a style of one particular author over the whole corpus. This selection of texts was preferred to the investigation of chosen fragments from longer works. Analysis of short papers gives a cross-cut of all components of a mathematical text.

The second data set, which we shall refer to as corpus B, consists of a transcription of 8 mathematical lectures (approximately 10 hours). The lectures were given during the summer term of 1985 in the Department of Mathematics at Christian Albrecht University in Kiel and at Hamburg

University (West Germany). The recorded lectures cover a variety of subjects and were given by mathematicians of different ages and experience. The list of texts is given in Appendix 1.

Apart from the investigation of the corpuses A and B we looked at some original German texts on mathematics written in the 19th century. Also we looked at German translations of Greek (Euclid) and Latin mathematical texts (Euler, Jacobi, Frobenius and Gauss).

The comparison between the data from written and spoken discourse (corpuses A and B) shows to what extent the immediate presence of the speaker and the audience influences the choice of referring expressions. By considering some examples of the older mathematical discourse we wanted to highlight the development of mathematical rhetoric and the influence of the individual style of particular authors. This is done in Chapter 5.

Investigating data from the spoken discourse, i.e. analysing the transcription of the recorded lectures, we often came across incomplete utterances, repetitions and even illegible fragments of discourse. The delimitation of clauses was carried out according to the content and form (syntax), and in the case of very long complex sentences also according to some intonational clues. Since for the purpose of this research we were mainly interested in the predicate-argument structures, we considered the question of sentence delimitation as a minor issue and concentrated on the clause analysis. Utterances lacking a predicate or with an incomplete predicate (e.g. with the auxiliary verb only) were ignored. The proportion of the discourse fragments left out was different for different speakers.

In written discourse, the syntax of mathematical formulae was left out of consideration since they do not contain any expressions that could be used to refer to the participants in the communicative situation. All omissions are indicated by /.../ . In transcription of recorded lectures no punctuation is used. Punctuation is used only in translation of German examples in Appendix 2 to facilitate their interpretation.

4.1.3 Research Methods

The data are investigated in order to find out what linguistic means are used in German for self-reference of the speaker in a restricted context

of scientific communication. We describe the data using the following criteria:

1. types of lexical predicates occurring in the text. We established a classification of predicate types according to the participant roles they prototypically involve and then linked up the predicate classes with discourse roles characteristic for a given restricted context. Since, as has been argued in the preceding chapters, the type of lexical predicate determines the prototypical participants, certain predicates could, in a restricted context, have their argument slots associated with particular discourse roles. This would further diminish the informative value of the lexical fillers in those slots and could be considered as one of the possible motivations for leaving some argument slots unfilled. The concept of a link between predicate types and discourse roles is further developed in Section 4.2.

2. other non-lexical characteristics of the predicate, such as Tense, Aspect, Mood, Voice and Modality. We consider Modality as 'non-lexical', concentrating on its reference-switching function. (The grammatical categories of verbal predicates involved in the subject-verb agreement, i.e. categories of Person and Number are considered in connection with the 1st participant of a predicate.) The non-lexical characteristics of the predicate are seen as deictic and bringing the subjective point of view of the narrator into the text.

3. definite, generalised and indefinite pronouns. We looked at the system of pronouns used in mathematical discourse to refer to the participants in the communication, i.e. to the speaker and to the audience (a distinction has to be made between the *immediate* audience and the *general* audience, i.e. the mathematical community of the time.) We are interested in finding out the rules that govern the referential use of generalised and indefinite pronouns. Since most of them can be used to refer to the speaker as well as to the audience, we are interested in conditions and constraints on their interpretation. We also investigate how the rules of interpretation could be accommodated within the classification of predicate types based on discourse roles.

4. other than pronominal ways of expressing deixis. The use of local and temporal deictic expressions in mathematical discourse is investigated. We look at expressions such as *here* and *now* and their co-occurrence with other deictic elements and with indirectly referring

expressions. We further analyse how the interpretation of local and temporal deictic elements is influenced by the presence of indirectly referential pronouns.

An exhaustive presentation of indirect reference in German is beyond the scope of this thesis. We concentrate on the indirect presentation of 'self' in one communicative domain, i.e. in mathematical discourse.

4.2 Predicate Frames and Discourse Roles

4.2.1 Semantic Classes of Predicates

In Subsection 3.1.3, we discussed systems of verb classification and indicated the predicate characteristics important in our research on indirect reference. In this section we present the verb classification system adopted in this thesis. Since the research presented here concerns reference patterns in scientific discourse, the adopted system was chosen to serve this particular purpose and no claims are made about its more general applicability.

In our model of verb semantics, we distinguish two levels containing information relevant for the interpretation of reference:

1. predicate frames and
2. discourse roles.

At the PF level, prototypical features of verb arguments are represented (as prototypical feature specifications at PF-slots). Consequently, we can distinguish between different verb classes according to different combinations of the type of lexical meaning and the set of prototypical participants (cf. Section 3.2). We draw a distinction between:

1. *action verbs*; their PFs contain at least two participating entities, one of them being the AGENT (prototypically human and volitional), the other one being the TARGET of the action. We further distinguish:

   i. *prototypical action verbs*, with a human agent and the target of the action physically affected;

   ii. *cognitive action verbs*, restricted to human agents, where action has an abstract, mental, i.e. not strictly physical character (the object is not physically affected) and the 1st participant is seen as a Processor;

   iii. *event verbs*, i.e. other verbs with at least two participants, that, however, cannot be seen as describing either prototypical or cognitive actions (e.g. verbs such as *helfen*, ('to help') *geben* ('to give') etc.) Sets of participant roles associated with the PF-slots are verb specific.

2) *middle verbs*; their PFs contain only one participating entity. Its prototypical status is a function of the lexical meaning of the predicate. There is no need to specify this relation since there is no source of confusion (i.e. no other participant that could be involved).

3) *relational verbs*; their PFs contain one or more argument slots with the feature OTHER (the fillers of those slots may be co-referential - different degrees of co-reference are possible) and a relation holding between them. We may further differentiate this class and distinguish between:

   i. *relational-equative verbs* as in:
      Das Resultat ist eine Funktion f(x)
      'the result is a function f(x)'

   ii. *relational-attributive verbs* as in:
      Die Menge von t ist kompakt
      'the set t is compact'

   iii. *relational-locative verbs* as in:
      Der Punkt m liegt auf der Ebene L
      'the point m lies on the plane L'

Only action verbs (possibly with exception of some event verbs) allow for passive voice. Lack of passive paraphrases for middle and relational verbs is motivated by their semantics - the inversion of an action is not possible, since there is no action in the prototypical sense.

The predicate classes distinguished above do not represent any complete verb classification system. (For instance, the classification does not have a class for proper *impersonalia*, i.e. verbs with no arguments, e.g. *regnen* ('to rain').) They are, however, sufficient for description of the language use in the restricted context of mathematical discourse.

4.2.2 **Pragmatic Classes of Predicates**

Having specified the prototypical features of the PF arguments, we introduce an additional dimension which is meant to represent the pragmatic information supplied by restricted context in which the language is used. This information is added to the prototypical

information stored in the lexicon.

We assume that a restricted context supplies a set of *discourse roles*. These discourse roles are associated with immediate participants in the communicative situation and/or with the physical or mental objects the discourse is about.

Let us consider as an example the restricted communicative domain of mathematical lectures. In this restricted context, verbs referring to the action of *knowledge transfer*, e.g. *lehren* ('to teach'), *zeigen* ('to show') etc., have some of their argument positions associated not only with features of prototypical participants but also with specific discourse roles. Therefore, participants in the communication sustaining those roles may be directly linked, i.e. identified with referents of the appropriate predicate argument positions.

In the restricted context of a mathematical lecture we shall distinguish between two major discourse roles - the speaker transferring his knowledge and the audience being the goal of the transmission. The first role is associated with the individual giving the lecture, the second with his immediate audience. This link remains constant in the restricted context specified above.

Discourse roles are further associated with certain argument positions of predicates related to the *transfer of knowledge*. For verbs such as e.g. *lehren* ('to teach'), *darstellen* ('to present'), *angeben* ('to give'), the 1st argument position is associated with the source of knowledge and the 3rd argument position is associated with the goal of the transfer. This link too, is constant in a given context. Figure 2 shows how the two dimensions are tied together and how they can be related to the actual discourse referents.

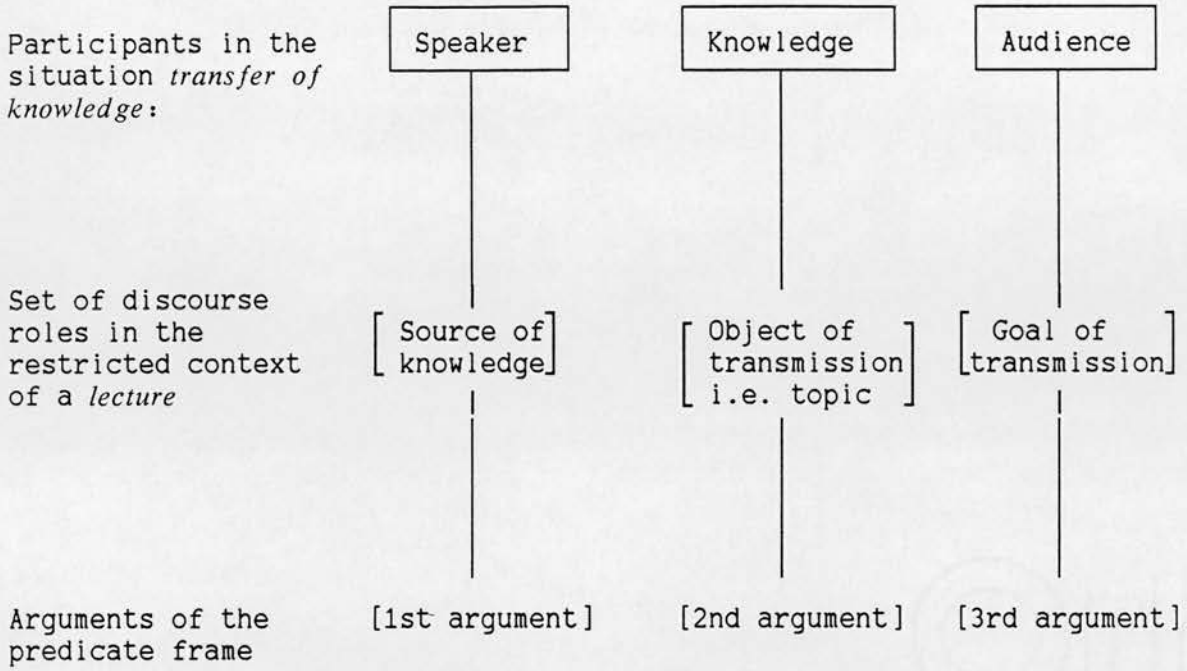

Figure 2. Link between participants in an event, discourse roles and PF argument slots for predicates related to knowledge transfer in a restricted context

The remaining 2nd argument position in PFs from this verb class has an open prototypical feature specification *object of transmission*. Even though this discourse role is generally linked with a specific lecture topic, this link exists at discourse level, not at clause level. Thus, at PF level, the 2nd argument position remains a variable whose semantics is given by the lexical filling of the appropriate PF-slot.

For verb pairs expressing reversible actions, e.g. *lehren/lernen* or *geben/bekommen*, there are two reverse discourse role assignments; i.e. the PFs have constant but different links between the referent of the 1st participant slot and the set of discourse roles provided by the restricted context. While for *lehren*, *darstellen*, *geben* etc., the referent of the 1st argument is the speaker, for verbs such as *lernen* ('to learn'), *bekommen* ('to receive') etc. it is the audience.

The diagram below shows how in the restricted context of a mathematical lecture, argument slots of a predicate related to knowledge transfer are *unified* with the set of context specific discourse roles.

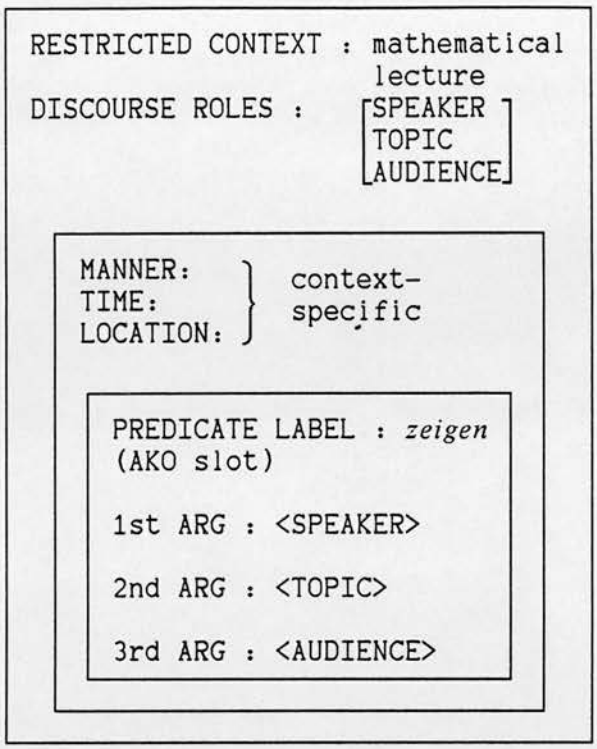

Figure 3. PF of the verb *zeigen* with argument slots associated with discourse roles characteristic for the restricted context of a lecture

Other groups of predicates, e.g. those describing cognitive actions labelled by verbs such as *denken* ('to think'), *verstehen* ('to understand'), *annehmen* ('to assume') etc., may have either the speaker or the audience as referents of their 1st argument position. The choice of an appropriate link depends not only on the lexical filling of the 1st argument slot on the PF. It may also be a function of the lexical filling of the 2nd argument slot corresponding to the object of the cognitive action expressed by the predicate, i.e. type of knowledge or belief may determine the reference link. One of the surface clues as to how to interpret some cognitive action predicates is the use of modal verbs.

In the following sections we show how the concept of indirect reference and discourse roles in restricted context applies to data from spoken and written German mathematical discourse.

4.3 Indirect Reference via Predicate Frame

4.3.1 Introduction

In this and the following section, we describe a means of indirect reference, particularly author's self-reference, in German mathematical discourse. In this section we concentrate on indirect reference via predicate frame. Other means of indirect reference, e.g. pronoun shift, reference by deictic elements and other lexical reference indicators, as well as the reference switching function of model verbs etc., are discussed in Section 4.4 . Syntactic and pragmatic conditions and constraints on interpreting indirect reference are summarised in Chapter 5.

As we pointed out in Chapter 3 (Section 3.2), the prototypical features specification of the predicate arguments is associated with PF-slots and is *inherited* by the frame copy when no lexical filler for a given slot is available. In the previous section of this chapter we discussed the question how, for certain semantic classes of predicates (e.g. those relating to the action of knowledge transfer), predicate arguments are linked together with discourse roles. Here, we apply both concepts in order to interpret impersonal and indefinite personal constructions used in written and spoken mathematical discourse.

Reference via predicate frame (i.e. indirect reference) is possible in the case of syntactic constructions that allow some argument positions to be left unfilled. In Subsection 3.3.3 we distinguished between omission of predicate arguments motivated by pragmatic reasons (ellipsis) and omission motivated by syntactic factors. In the first case, the referents may be identified by linking unfilled PF-slots with discourse roles known from the immediate context. Referring merely to the prototypical feature specification on PF argument slots would not be enough to achieve successful identification of discourse referents in most of the non-specific (i.e. not formalised) contexts. This is why, as we argued, context motivated, and consequently context dependent, ellipsis is possible only where the same immediate situational context is accessible both for the speaker and his audience.

In the case of omission justified by syntax, the argument is first demoted from its neutral (according to the PF specification) position,

it becomes a *chômeur* (i.e. it loses its syntactic function, which is taken over by another argument), and as such it can be left out. In German and in other Indo-European languages, this is the case for passive and reflexive constructions where the 1st argument of the predicate frame may be or must be omitted in the clause structure. In our data from mathematical discourse, we find instances of indirect reference of both types. Their common feature is that to infer the intended reference it is necessary to relate the actual structure of a clause to the matrix predicate frame. Let us discuss the examples found in the data, starting with constructions where there is no demotion of the omitted argument down the hierarchy of grammatical relations.

4.3.2 *Man*-Clauses

A simple example of a construction with an argument not demoted but also non-lexical is the German *man*-construction. *Man* always takes the syntactic subject position in constructions with predicates that have prototypically human 1st participants. An exception is the passive construction with the subject *man*, as e.g. in (1):

(1) Man wird oft gefragt....
'one is often asked...' .

This is possible only for predicates which have no prototypical semantic constraints (or simply allow the feature + HUMAN) on arguments that correspond to the passive subject *man*. Predicates such as *behaupten* ('to presuppose') or *annehmen* ('to assume'), with 2nd arguments prototypically related to the feature + ABSTRACT, do not permit passive with the subject man:

(2) *Man wird angenommen...
'one is assumed...'
*Man wird behauptet...
'one is presupposed...' .

If the subject position is filled by *man*, no other lexical element can be added (neither as apposition nor by conjunction). The examples in (3b and c) are ungrammatical:

(3) a. Man beweist den Satz wie folgt
'one proves the theorem as follows'

b.*Man, der Autor beweist den Satz wie folgt
'one, the author, proves the theorem as follows'
c.*Man und der Autor beweisen den Satz wie folgt
'one and the author prove the theorem as follows' .

Although *man* is a proper syntactic subject (i.e. it can be substituted for lexically fully specified expressions such as *der Autor* or *E. Landau* etc. without causing any changes in the syntactic structure of the clause), it does not add any semantic or referential information to the prototypical feature specification available in the PF for a given argument position. *Man* functions as a surface representation of the PF semantic prototype, constituting a unique example of this sort in the language system of German.

To establish reference of the *man*-expressions used in scientific communication, this prototypical semantic information is not sufficient. However, it seems that in the restricted context of mathematical discourse, the so called *indefinite personal* pronoun *man* has definite, though not constant, referents. The referential link can be established by introducing the additional pragmatic dimension of *discourse roles*, discussed in the previous section. Thus, it is the pragmatic class of the predicate which determines the referential link for indefinite referring expressions. We illustrate this point with some examples, first from the spoken, then from the written discourse. (Translation of all discourse examples is given in Appendix 2.)

Example 4.1:

...jetzt wollen wir sagen wir haben einen operator/dissipativ/nun/das könnte unser letzter teil für heute sein/definition/t von x dt nach x linear t heißt dissipativ genau dann wenn für alle x aus dt existiert ein x strich aus f von.../also ein funktional/so daß der realteil von x strich angewendet auf tx/daß der kleiner gleich null ist/da *glaubt man nie im leben daß man damit was anfangen kann*/ich geb' deswegen gleich mal den satz an/.../wir beweisen ihn das nächste mal aber ich mag sie mit dieser definition nicht ins wochenende gehen lassen weil wie gesagt *man glaubt nicht daß man damit irgendwas anfangen kann*/.../das ist so eine gleichmäßige beschränktheit dieser abbildung nach unten/das heißt also wenn das ding hier surjektiv wäre/injektiv ist es/*dann hat*

man genau eine abschätzung wie man sie braucht für Hiller Phillips/denn man hat sie einfach aus dem inversen operator hier von/.../ das heißt also *wenn man auf irgendeine art und weise sicherstellen kann* daß das t abgeschlossen ist und ja irgendwie mal surjektiv *dann hat man schon die voraussetzung/.../*und... stellt sich wirklich heraus so verrückt diese bedingung hier irgendwie aussieht *daß man sie wirklich relativ einfach nachrechnen kann/.../man hat sich ein x aus dt herzunehmen* und *muß dann so ein x strich aus fx finden/wobei man nicht weiß wie schwierig es ist fx zu bestimmen/aber man muß's sich dann nur noch angucken/muß keine norm ausrechnen/*nichts/*sondern man läßt irgendein funktional los auf tx/*und *wenn man jetzt die norm ausrechnen wollte* von irgendwie tx oder so/*dann müßte man alle funktionale nehmen/...*oder so/...

(B-1)

Example 4.2:

C) Rationale Homotopie von S^1-Faserungen. Im folgenden suchen wir eine Mannigfaltigkeit mit $H^*(B,Q)\cong H^*$ und eine S^1-Faserung $p:E\downarrow B$, so daß E und M rational homotopieäquivalente Mannigfaltigkeiten sind. B soll zunächst als rationaler Raum konstruiert werden, wobei wir Sullivan's rationale Homotopietheorie heranziehen.

...

Satz 2.8. Sei $p:E\downarrow B$ eine S^1-Faserung. Dann gibt es... *Satz 2.8. erhält man leicht* aus einem Satz von Grivel. Die letzte Gleichung in Satz 2.8 soll als "Differentialgleichung" verstanden werden, *die man Grad für Grad lösen muß:*... Dann muß gelten... Die rechte Seite ist bestimmt, da $d_E(X)$ zerlegbar ist.

D) Aufbau freier S^1-Operationen bis auf rationale Homotopieäquivalenz. *Kann man τ wie in Satz 2.8 angeben,* so induziert die kurze exakte Sequenz..., p die Augmentation, eine der Gysin-Sequenz ähnliche lange exakte Sequenz... *Man möchte nun τ* - und damit d_B - *so wählen,* daß obige Sequenz durch eine Leiter von Isomorphismen verbunden werden kann...

(A-7)

It is obvious that in both fragments *man* is not used as indefinitely referential. Even though in most of the examples above no individual can be selected as referent of *man*, the referential link is definite and is determined by the set of statements predicated of the subject *man*. Thus, even in an apparently homogeneous fragment of discourse, we may find instances of *man* which do not allow for the same interpretation, e.g. because they are associated with predicates related to different discourse roles.

In examples 4.1 and 4.2, most instances of *man* may be interpreted as referring to the general audience, i.e. to 'those who want to follow the argument presented and have all necessary knowledge to do so'. In most cases (e.g. in the first four instances in example 4.1), the author does not exclude himself from that group in any explicit way. However, an exclusion of this sort is possible and it can be illustrated with another example in fragment 4.1, which we repeat here for convenience:

(4) a. ...wobei man nicht weiß wie schwierig es ist fx zu bestimmen...
'...where one does not know how difficult it is to estimate fx...' .

Here, the author clearly excludes himself from the group (referred to by *man*) of those who do not know how difficult the problem is. The author *knows* the answer and he confirms this in the two following statements.

(4) b. ...aber man muß's sich dann nur noch angucken/muß keine norm ausrechnen...
'...but one only has to take a glance at it/one does not need to calculate the norm...' .

A different case of narrowing the reference scope of *man* is illustrated by an expression in example 4.2, repeated below:

(5) ...*Man möchte* nun τ ... *so wählen*, daß die obige Sequenz... durch eine Leiter von Isomorphismen verbunden werden kann...
'...one would like to choose τ in such a way that the above sequence can be connected by a ladder of isomorphisms...' .

Fragment 4.2 is taken from a paper written by **two** authors. Due to this fact, the pronoun *wir*, which is the neutral indirect way of the author's self reference in scientific discourse and which also allows for the desired more general reading, becomes directly referential. Consequently, in text A-7 *wir* is used to refer to the particular actions and achievements of the authors (i.e. it is used as *directly referential*). The neutral function of the generalised *wir* is taken over by *man*. In example (5) (from fragment 4.2), however, *man* occurs together with the modal verb *mögen* and this particular element seems to redirect the reference interpretation and to narrow it to the authors' reference to themselves. Different modal verbs have different reference switching properties and we discuss this question in more detail in Section 4.4. Other examples of definite, though varying reference of the pronoun *man* are discussed in Subsection 4.4.1, where we relate this question to the *pronoun shift* and analyse dependencies in the system of pronouns used in a restricted context.

German constructions with the pronoun *man* in subject position constitute the only example of a syntactically neutral structure where the constituent corresponding to the 1st argument of the PF is lexically empty (i.e. does not add any extra information to the PF prototypical semantic feature specification) but not demoted down the hierarchy of grammatical relations. Now, we discuss an example of a regular omission of one argument position in a particular class of predicates.

4.3.3 **Reduced Valency**

In Section 4.2 it was pointed out that in the restricted context defined by a lecture or by a particular mathematical paper, predicates related to the action of knowledge transfer, such as *(an)geben* ('to give'), *darstellen* ('to present'), *zeigen* ('to show'), have their 3rd argument position associated with the discourse role of the goal of transmission. This argument position is further linked with the immediate audience or in the case of a mathematical paper also with the general audience. Because this link remains constant in a given restricted domain, any lexical filling of the 3rd argument slot would be interpreted as referring to the audience. Since the reference of that argument is expected, the informative value of the lexical filler is null and the filler becomes redundant. Consequently, we observe a regular change in the valency of trivalent verbs related to the knowledge transfer. The 3rd argument position of predicates such as *(an)geben* or *zeigen* is

especially well suited for this regular omission. Firstly, in German the 3rd argument cannot be advanced to the syntactic subject position. It remains associated with the Dative case marking even if the 2nd argument becomes subject. 1st arguments, which are naturally selected for syntactic subjects, cannot be omitted without major changes in the syntactic structure of the clause. This is due to the fact that German finite clauses (apart from few exceptional cases) must have an overt grammatical subject. Omission of the 3rd argument does not cause any rearrangements of the syntactic structure.

The second reason is more complex and relates to the problem of indirect reference. The most common way of achieving self-reference in scientific discourse is with the generalised *wir*. In most cases *wir* may be interpreted as referring either to the speaker only or to the speaker and the audience or, eventually, to the audience only. Consequently, the most suitable form to be used as a lexical filler of the 3rd argument slot would be the Dative form of the 1st Person Plural pronoun, i.e. *uns*, as in (6):

(6) *wir* geben *uns* jetzt den Beweis dafür
'we are now giving ourselves a proof for this'.

Example (6) is grammatical only if we accept the co-referential interpretation of *wir* and *uns*. One cannot interpret *wir* as e.g. author's indirect self-reference and *uns* as indirectly referring to the audience. However, if *wir* and *uns* are to be co-referential, the statement in (6) seems to be slightly awkward: it would mean that either the speaker presents something (here the proof) to himself, or that the speaker and the audience work together to present something to themselves. Both interpretations would be rejected because they do not match the pragmatic discourse roles assignment discussed in Section 4.2. Moreover, the convenient general pronoun *man* cannot be used since it does not possess a Dative form. The alternative form *einem* suggests a singular referent interpretation and this is not a desirable one. Any expressions referring to the immediate or general audience in a more explicit way, e.g. *euch*, *ihnen* ('to you'), *allen* ('to everybody'), *den Leuten* ('to the people') or *der ganzen mathematischen Gemeinschaft* ('to the whole mathematical community') are either too narrow or simply do not comply with the rhetoric of science. Therefore, the *regular decrease in valency* is the most appropriate and pragmatically neutral solution.

Let us illustrate this point with some examples from the written (corpus A) and spoken (corpus B) mathematical discourse.

(7) *Wir zeigen* hier unter anderem, daß diese Vermutung richtig ist...
'we show here among other things that this conjecture is correct...'

(A-7)

(8) Im Abschn. 3 *zeigen wir* dann, wie man Z/p^n-Operationen... verschiebt, um zu Satz 1.0 zu kommen
'in section 3 we show then how one shifts the Z/p^n-operations... to arrive at theorem 1.0'

(A-7)

(9) Der Beweis dieser beiden Sätze *wird* in Abschn. 5 *gegeben werden.*
Die Sätze 3.1 und 3.2 *wurden* von Jones ... *angegeben.* Satz 3.2 folgt leicht aus... . Da ***uns*** die dort angegebenen Beweise nicht völlig klar sind, haben wir Beweise im Abschn. 5 ausgeführt. Andere Beweise hierfür *sind* von Assadi ... *gegeben worden*
'the proof of these two theorems will be given in section 5. theorems 3.1 and 3.2 were given by Jones... . theorem 3.2 follows easily from... . since the proofs given there were not absolutely clear for us we have derived them in section 5. other proofs for this were given by Assadi...'

(A-7)

(10) Ist die Bedingung ... nicht erfüllt, so *kann man* immerhin noch *sagen*...
'if the condition ... is not satisfied, one can still say...'

(A-7)

(11) In diesem Abschnitt *werde ich zeigen*, wie man mit diesen Resultaten auch Realisierungen zusammengesetzter endlicher Gruppen ... erhalten kann
'in this section I shall show how, with these results, one can get also the representations of the complex finite groups...'

(A-11)

(12) Folgerung 2b) *liefert* nun die Behauptung für die Gruppe $G = M_{12}$
'conclusion 2b) gives then the statement for the group $G = M_{12}$ '

(A-11)

(13) Für die sporadischen einfachen Gruppen *stehen* keine bequemen Matrizendarstellungen *zur Verfügung*, dagegen sind die Charaktertafeln alle vorhanden
'for sporadic simple groups no convenient matrix representations are available, whilst the character tables are all at hand'

(A-11)

(14) *Wir zeigen* jetzt, daß es zu jedem *x* eine Möglichkeit gibt, *xy* für alle *y* so zu definieren, daß...
'now we show that for each x it is possible to define xy for all y in such a way that...'

(A-5)

(15) ...*wir werden* nämlich *zeigen* daß wenn die zahl n minus eins auf irgendwelche weise in ganzzahlige faktoren alpha beta gamma und so weiter ... zerlegt wird/x in alpha faktoren ... zerlegt werden kann...
'...we shall namely show that if the number n-1 can somehow be resolved into integer factors α β γ and so on ... then x can be resolved into α factors...'

(B-2)

(16) *Er hat die Frage gestellt*, ob eine beliebige abgeschlossene Menge, die ..., die Nullstellenmenge der charakteristischen Funktion ist
'he posed the question whether an arbitrary closed set which ... is a set of zero values of the characteristic function'

(A-9)

(17) ...*wir wollen zeigen*, daß es nur endlich viele zwischenkörper gibt zwischen l und k...
'...we want to show that there are only finitely many intermediate fields between l and k...'

(B-3)

In the examples above, the predicates *zeigen*, *geben*, *zur Verfügung stehen* ('to be at sb's command'), *sagen* ('to tell') etc. are used as bivalent, and the 3rd argument, which would express reference to the audience, is omitted. This omission is to be explained by the pragmatic, context determined, reference link between predicate arguments and discourse roles. The omitted 3rd argument in examples (7)-(17) is linked with the general audience. The intended reference of the 3rd argument for this set of predicates does not depend on the reference of the 1st argument position. In (16) the *general* interpretation of the unexpressed 3rd argument is possible although the 1st argument is not linked with the author. In this example, the predicate *eine Frage stellen* ('to ask a question') is associated with the 3rd Person Singular definite pronoun *er* in subject position. The general interpretation of the 3rd argument is obvious because of the semantics of the 2nd argument, linked with the presented fragment of knowledge.

Where the 3rd argument is to be linked with referents unexpected in the restricted context, the reference is made explicit. One example of this sort is given in (9), where an extra position (filled with the Dative form *uns*) is added to the relational-attributive PF. This was necessary to narrow the scope of the predicate *nicht klar sein* ('not to be clear') and to restrict it, for rhetorical reasons, to the authors only. Below we give more examples of trivalent predicates with all valency positions lexically specified, due to the fact that the 3rd argument position is no longer associated with the expected referent. Examples illustrating this phenomenon were found almost only in the spoken mathematical discourse. The only examples in the set of data from written discourse come from the very informal introduction to a student manual by Edmund Landau, whose specific language we discuss further in Section 4.5. One example from Landau is quoted below as (18).

(18) ...*ich empfehle Dir* aber als Übungsaufgabe zu Kap.1, §4,

$$2 = 1 + 1$$

$$4 = ((1 + 1) + 1) + 1$$

zu definieren und jenen Satz zu beweisen.

'as an exercise to ch.1, §4, however, I recommend you to define ... and to prove the above therem' .

(A-5)

Examples, (19)-(21), are taken from a lecture where the work of Carl Friedrich Gauss was discussed in a historical perspective. There, it

was often the case that the predicate argument linked with the *source of knowledge* was associated with an individual referent, i.e. Gauss, and the *goal* argument was associated with a specific group referent, i.e. with those studying Gauss' theory. This change in the neutral discourse role assignment is made explicit by a full lexical specification of valency for predicates related to the transfer of knowledge.

(19) ...und was macht Gauss dazu?/nun wir gehen sozusagen von einer Galois-korrespondenz.../von so einem zwischen-körper m herüber zu einer untergruppe u/und dann *wird Gauss uns* gleich *zeigen* daß.../nun das wissen wir schon...
'...and what does Gauss with this?/well we move over, say, from Galois correspondence.../from such an intermediate field m to a subgroup u/and then Gauss will immediately show us that.../well we know this already...
(B-2)

(20) ...das macht Gauss auch so alles/dann hat man eta null als nullstelle eines polynoms vom grade e/also lösung einer gleichung vom grade e/nicht?/und dann hat er jedenfalls diesen körper hier im griff/dann *kann er das* wieder *uns beweisen/zeigen* daß dieses eta null hat...
'...and all this Gauss also does/and then one has η_0 as zero value of the polynomial of degree e/i.e. the solution of an equation of degree e/yes?/and then he has the feel of this field here/and then again he can prove it to us/show that this η_0 has...'
(B-2)

(21) ...jetzt hat er (i.e. Gauss - M.S.) *uns schon erzählt* daß dieses symbol/eckige klammer/abhängt von r ...
'...now he has already told us that this symbol/[]/ depends on r...'
(B-2)

If a simple deictic reference interpretation is desired and the speaker refers to himself using *ich*, he addresses his immediate audience in a direct way and the 3rd argument position is lexically filled by *Ihnen* as in (22):

(22) ...da *hab ich Ihnen* also *mitgebracht* hier aus den disquisitiones arithmeticae auf deutsch/habe eigentlich

hier auf lateinisch/*werde Ihnen* nachher einen schönen lateinischen satz *vorlesen*/.../also das schließt sich an die seiten die *ich Ihnen* da *gegeben habe* an...
'...so I have brought you here along from the disquisitiones arithmeticae in German/actually I have it here in Latin/(I) shall read you later aloud a nice Latin sentence/.../so this goes together with the pages that I gave you...'

(B-2)

Examples such as (22) are related to what the speaker actually does in the classroom. They contain predicates other than those relating to the transfer of abstract knowledge (such as *darstellen*, *zeigen* etc.). *Vorlesen* ('to read aloud') and *mitbringen* ('to bring along') describe real actions performed by the speaker. Even the predicate *geben* ('to give'), as used in (22), has its non-specific, literal meaning and as such has all its argument positions filled.

In the spoken discourse we found also instances of *free Datives*, i.e. constituents with Dative case marking, having no complement status, coreferential with the clause subject. They are characteristic mainly for an informal way of speaking. The morphological form found most often was the Dative of the 1st Person Plural pronoun, *uns* as in (23)-(24):

(23) ...zum vorgegebenen x *definieren wir uns* sätze...
'...for a given x we define us statements...

(B-1)

(24) ...jetzt denken wir uns.../wir denken uns.../erinnern uns an diese ... schnittpunkte...
'...now we think.../we think.../(we) recall these points of intersection...'

(B-8)

The 1st Person Singular form *mir*, as in example (25), was also found in our data:

(25) ...wichtig war *mir* die verbindung zwischen der differenzierbarkeit und dem begriff der...
'...for me the important thing was the link between the differentiability and the concept of ...' .

(B-4)

In the examples (9) and (25) we have the Dative pronouns *uns* and *mir* associated with complex predicates *klar sein* ('to be clear') and *wichtig sein* ('to be important'). The pronominal forms in these examples cannot be interpreted as synatactically and semantically empty. Syntactically, they function as Dative objects. Semantically, they restrict the scope of validity of the predicate.

We have discussed so far two, syntactically very simple possibilities of indirect reference, i.e. the *man*-clauses and the examples of a pragmatically justified decrease in valency. German syntax allows for a wide range of other, more complex, indirect ways for the author to achieve self-reference as well as reference to the audience. Below, we discuss indirect reference via:

1. passive constructions,
2. infinitival constructions,
3. *Streckformen*, i.e. predicates consisting of a semantically neutral verb and a nominal predicative,
4. other nominal constructions.

4.3.4 **Passive**

As was pointed out in Chapter 3 (Sections 3.2 and 3.3), passive constructions with some predicate arguments missing are interpreted by filling the appropriate slots in the current PF-copy with the prototypical semantic feature specification from the matrix PF or from the previous PF-copy. Schematically, this can be done e.g. by activating the 'If-removed' facet on the argument slot (cf. Subsection 3.2.1). Then the prototypical semantic information about arguments as well as the referential extra information provided by the restricted context (i.e. the information on the discourse roles assignments) becomes accessible. If we adopt this mechanism of reference interpretation both the personal and the impersonal passives with predicates associated with human 1st participants (in the restricted context considered) can be interpreted as *personal*, i.e. the complete set of participants can be retrieved.

Let us consider some examples to illustrate this point.

(26) Dieser Satz sagt also aus, daß alle Maßtheorien nur durch Umrechnung aus der additiven entstehen. Sein Beweis *war am angegebenen Ort* sehr umständlich und unübersichtlich

geführt. *Es soll nun hier* ein ganz kurzer und durchsichtiger Beweis *gegeben werden*
'this theorem states that all measure theories are obtained by conversion from the additive one. its proof was derived there in a very complex and obscure way. here, a very short and clear proof shall be given' .

(A-8)

In (26) we have a sequence of two agentless passive constructions. In both cases the explicit reference to the *agent* is missing (i.e. there are no agentive prepositional phrases) and, apparently, the co-referential interpretation of the missing agents is not desired. This is indicated by the contrastive use of tenses (*Präteritum* versus *Präsens* with a modal verb) and other contrastive deictic elements (*am angegebenen Ort* versus *nun hier*) as well as by contrastive adjectives (*umständlich* and *unübersichtlich* versus *kurz* and *durchsichtig*). The temporal and local deictic markers (and in fact also the evaluative expressions) seem to link the missing agent of the first passive construction in (26) with a different individual than the current narrator, who is clearly the referent of the missing agent expression in the second passive construction. However, the two missing agents in (26) are co-referential and the two agentless passives are forms of the author's indirect self-reference. The referential link is made explicit at the beginning of the paper in the opening phrase in (27):

(27) *An anderer Stelle*[1)] *habe ich* alle Inhaltstheorien *betrachtet*, die folgenden vier Axiomen genügen
'at a different place[1)] I considered systems of sets that satisfy the following four axioms' .

(A-8)

After this link has been established, all instances of self-reference are indirect (*man*-clauses, impersonal passives etc.) and the desired interpretation of the indirectly referring expressions is indicated by various temporal or local deictic elements (cf. further discussion in Subsection 4.3.5).

The contrast made in (26) may be interpreted in terms of the author's intention to distance himself from his own earlier results, since his theory has improved. In the case considered above, the co-referential interpretation of the two missing agents was correct despite the contrastive form used. However, an analogous contrast could be used to

express reference switching if the two inherent agents were not co-referential. This clearly shows that reference switching could be achieved even if no directly referring expressions were present in the clause surface structure.

Agentless passives can be interpreted in terms of the author's indirect self-reference or as instances of his reference to the definite (immediate or general) audience. This interpretation may result from the semantic class of the predicate and its assignment of discourse roles. Below we give some more examples to illustrate the use of the passive in German mathematical discourse.

(28) *In §3 gabeln wir* das Axiomensystem A an dem Axiom von der Existenz der Verbindungsgeraden. (author's indirect self-reference using generalised *wir* and supported by the local phrase *in §3* - M.S.) Das Axiomensystem A, zusammen mit der Existenz der Verbindungsgeraden, ist äquivalent mit dem Schmidt-Bachmannschen Axiomensystem, für das der Hauptsatz 1 *schon in [4] bewiesen ist*. (indirect reference to the author of the paper *[4]* via PF of the agentless *Zustandspassiv* - M.S.) Für das Axiomensystem A,... *wird* der Hauptsatz 1 *in Teil II bewiesen* (author's indirect self-reference via PF of the agentless *Vorgangspassiv*, supported by the local phrase *in Teil II* - M.S.)
'in §3 we append the system of axioms A with the axiom of existence of the straight line connecting two points. the system of axioms A, together with the existence of the connecting line, is equivalent to the Schmidt-Banach system of axioms, for which the main theorem 1 has already been proved in [4]. for the system of axioms A, ... the main theorem 1 will be proved in part II'

(A-12)

(29) Das Problem der Einbettung topologischer Ringe in Quotientenringe *wurde* ... wohl erstmals *von Gelbaum-Kalisch-Olmstedt* [5] systematisch *untersucht* (direct reference via agentive phrase - M.S.)
'the problem of embedding topological rings in the quotient rings was for the first time systematically investigated by Gelbaum, Kalisch & Olmstedt [5]...'

(A-10)

(30) Der Begriff des generalisierten Nullteilers stammt aus der Theorie der normierten Algebren (vgl. auch Arens [2]) und *wurde* bereits *von Andrunakievič-Arnautov* [1] auf beliebige topologische Ringe *übertragen*. (direct reference via agentive phrase - M.S.)
'the concept of the generalised null divisor originates from the theory of algebras with norm (cf. also Arens [2]) and has already been applied to arbitrary topological rings by Andrunakievič & Arnautov [1]'

(A-10)

Actions such as *beweisen* ('to prove'), *definieren* ('to define'), *formulieren* ('to formulate'), *untersuchen* ('to investigate'), etc., in a restricted context defined by pragmatic features characteristic for a lecture or scientific paper, are prototypically predicated of the speaker/author. If this link is to be redirected, an overt, explicit indication is needed, e.g. by means of some definite local adverbials or, in fact, by fully specified agentive phrases as in (29)-(30). In (28) local deictic indicators support self-referential (or definite personal) interpretation although no other means of reference are overtly used. Deictic elements may favour self-referential interpretation even if the discourse roles assignment for a predicate does not point to the author as the most likely referent of the 1st argument.

4.3.5 **Infinitival and Participial Constructions**

Apart from simple and modalised passives used as means of indirect reference, we find a wide range of infinitival or participial constructions as well as numerous examples of nominalisation. There, again, the interpretation results from the appropriate link between the unfilled PF-slots and discourse roles (for predicate classes with specific discourse roles assignments) or the prototypical semantic features. We shall examine how the PF reference interpretation applies to other constructions. Let us first consider an example with the construction *sich lassen* + *Infinitiv*:

(31) Mit den Bezeichnungen von Figur 1 *lässt sie sich* folgendermassen *beschreiben*
'in notation of figure 1, it can be described as follows'.

(A-2)

In the restricted context, the 1st argument position of *beschreiben* ('to describe') is prototypically associated with the author. However, if the PF of *beschreiben* is embedded in a construction with *sich lassen*, the 1st participant slot of the verb *beschreiben* is not filled with lexical material. Consequently, (31) may have a *general* reading, i.e. it simply expresses a certain property of the figure in question (pyramid), a property which does not depend on *who* does the describing. Paraphrases of (31), e.g. *kann beschrieben werden*,, or *man kann beschreiben* do not allow for the same degree of blocking for the definite personal (i.e. individual) interpretation. A similar general reading is allowed in constructions with *sein + zu + Infinitiv*. We shall discuss later this type of infinitival clause in more detail.

Since the construction *sich lassen + Infinitiv* has the most general reading, it is a useful way of expressing mathematical statements where, e.g., a certain property is attributed to certain objects as a result of human cognitive actions such as *defining* or *describing*. Thus, this construction is often used in written discourse, especially in theorems and proofs, e.g.:

(32) Lemma 3.2. Sei E eine abgeschlossenne, symmetrische Teilmenge des R^N, die den Nullpunkt nicht enthält, und die bezüglich ... periodisch ist. *Dann läßt sich E in der Form ... darstellen*, wobei die Mengen e k j N-dimensionale Grundmengen sind
'lemma 3.2. let E be a closed symmetric partial set of R^N which does not contain zero, and which is periodic with respect to... . then, E can be represented as ... where sets e k j are N-dimensional basic sets'

(A-9)

(33) Deshalb genügt es, zu zeigen, *daß sich die Mengen ... in der Form (4) darstellen lassen*
'therefore it is enough to show that sets ... can be represented as in (4)'

(A-9)

(34) Mit Hilfe der Gysin-Sequenz *lassen sich* weitere Bedingungen an H*(M) *angeben*
'using Gysin sequence further conditions on H*(M) can be specified'.

(A-7)

In (32)-(34) above, the verbs *darstellen* and *angeben* are used in infinitive constructions. This allows the 1st participants of the predicates to be left out syntactically and, consequently, also semantically. Thus, the construction in (33) is interpreted merely as an attribution of a property *darstellbar sein* to the syntactic subject. The constituent functioning as subject of (33) corresponds to the 2nd argument of the predicate *darstellen*. This type of infinitive construction is often seen as a passive paraphrase. As far as the interpretation of reference is concerned, it represents a higher degree of backgrounding of the 1st participant. In the spoken mathematical discourse, more informal clauses with subjects *man* and *wir* are used instead.

Below we discuss other infinitival constructions, *um + zu + Infinitiv* and *haben/sein + zu + Infinitiv*.

The *um + zu + Infinitiv* construction is a typical, neutral form of German *Finalsatz*. The referent of the overt subject of the main clause is identical with the referent of the 1st argument in the PF of the verb in the infinitive. Since this referential identity can be achieved without repeating explicit (even if indirect) reference to the human participant, we would expect the *um + zu + Infinitiv* construction to be often used in certain parts of mathematical discourse (e.g. in proofs and in comments on methodology). This was confirmed by the data:

(35) Um (2.2.f) *sicherzustellen*, muß man von diesem Rezept evtl. in einem Punkt abweichen
'to guarantee (2.2.f) one possibly has to diverge from this formula at one point'
(A-7)

(36) *Um ... zu definieren*, verkleben wir ... entlang ... mit...
'to define ... we fasten ... down along with...' .
(A-7)

The *um + zu + Infinitiv* construction occurs almost exclusively in the written discourse, most probably because the syntactically more complex structures are generally avoided in the spoken language. Instead of complex sentences, we find sequences of relatively simple clauses. This is illustrated in the discourse fragment 4.3 below:

Example 4.3

...das problem das man *zunächst* hat ist überhaupt zu sehen daß

diese menge nicht leer ist/also *erstens* r x ist nicht leer/na ja/wenn x gleich null ist hat man keine großen schwierigkeiten/nicht?/nur wenn x ungleich null ist/also daß die geschichte nicht leer ist/ja *dann* nutzen wir einfach den Hahn-Banach aus/so machen wir es einfach so/zum vorgegebenen x definieren wir uns sätze/tja/wie machen wir das?/wie nennen wir das?/fi von x sei norm ... und zwar weil wir fi auffassen als abbildung vom erzeugnis von x .../*und* wir setzen diese abbildung linear fort/.../*und* fi wollen wir machen zu einer linearen abbildung auf dem erzeugnis von x mit werten im körper/wir machen es einfach ganz brutal/wir setzen also linear fort...

(B-1)

In 4.3 the causal dependencies between clauses are expressed by means of inserted questions (*wie machen wir das?* ('how shall we do this?'), *wie nennen wir das?* ('how shall we denote this?')), by simple temporal adverbs such as *zunächst*, *erstens* and *dann* or by the conjunction *und*.

Infinitival constructions found more often in the spoken discourse are those involving verbs *sein* and *haben* + (zu +) *Infinitiv* in various configurations as illustrated in (37)-(40).

(37) ...so schön diese bedingungen von Hiller und Yosida auch sind/sie *sind* im allgemeinen *schwer nachzurechnen*/also *es ist* im allgemeinen *schwierig* resolventenabgleichung/ resolventenabschätzung *zu finden*/.../*es ist leicht* so was *auszurechnen* aber so was *auszurechnen ist* schon *unangenehm*...
'...although these conditions by Hiller and Yosida are nice they are generally difficult to check/i.e. it is generally difficult to find the adjustment of the resolvents/the estimation of resolvents/.../it is easy to calculate something like this but it is quite unpleasant to calculate something like this...'

(B-1)

(38) Es *sind* zunächst einige Begriffe *zu erläutern*
'there are first some concepts to explain'

(A-4)

(39) ...nun wenn ich das ut darauf ... anwende dann *habe ich* das maximum nun noch *zu nehmen*...
'...well if I apply ut to this ... then I only have to take the maximum...'

(B-1)

(40) ...*man hat sich* ein x aus dt *herzunehmen*...
'...one has to take an x out of dt...' .

(B-1)

(Note that in (40) we also have a free Dative constituent co-referential with the subject *man*.)

Again, as was the case for *sich lassen* + *Infinitiv*, the 1st argument positions of the main verb in *sein* + *zu* + *Infinitiv* in (37)-(38) are blocked, i.e. (41a) is awkward

(41) a. sie sind *von uns* schwer zu finden
'they are **by us* difficult to find'

and (41b) ungrammatical

b. es ist schwierig sie **von uns* zu finden
'it is difficult to find them **by us*' .

For trivalent verbs, such as *geben* ('to give'), lexical filling of the 3rd argument position is also considered as stylistically marked (as contrastive), cf. (42):

(42) Der Beweis ist *euch/Ihnen* zu geben
'the proof is to be given *to you*' .

In constructions with *sein* + *zu* + *Infinitiv*, such as those in (37)-(38), the 2nd argument in PF of the main verb is advanced to the clause subject position. It seems that the *zu* + *Infinitive* form of the verbal predicate changes the predicate-argument structure from a fully specified PF to a relational-attributive frame with a deverbal attribute.

The examples in (39) and (40) with *haben* + *zu* + *Infinitiv* have a different syntactic structure and consequently require different semantic (and referential) interpretation. The 1st participant of the main verb *nehmen* ('to take') is co-referential with the 1st participant of *haben*, i.e. no PF-slots are blocked. The *hat* + *zu* + *Infinitiv* construction,

used mainly in the spoken discourse, may be seen as a direct though slightly informal paraphrase of the *muß + Infinitiv* construction, standard in the written discourse. The *haben + zu + Infinitiv* constructions are used as means of indirect reference simply by filling subject position by *man* or the generalised *wir*.

A truly *impersonal* function can be attributed to constructions such as the one in (43):

(43) Wegen...genügt es zu zeigen, daß...
'because of... it is enough to show that...'.

Here, the infinitive of the verb *zeigen* ('to show') has the 1st participant slot blocked since the finite verb *genügen* ('to be enough'/ 'to satisfy') cannot be associated with human 1st participants. It usually occurs with the dummy *es*. The construction can be used only if there is no need to identify the referent of the 1st argument of the main verb, e.g. if no specific referent is intended. Constructions illustrated in (37),(38) and (41)-(43), are interpreted as *general*, i.e. as referring to the principles of mathematical argumentation rather than to any particular actions of any individual referents.

One could expect that this type of infinitival construction would be used as well if the referent of the 1st argument slot was already known or identified and if there was no other competing referent in the discourse domain. This could be the case in the immediate situational context of the spoken mathematical discourse. Theoretically this assumption is likely to be true. However, in spoken discourse generally, more *personal* constructions are preferred. To achieve a general reading pronoun shift would probably be used instead, as illustrated in (44):

(44) ...es genügt wenn wir nun zeigen daß...
'...it is enough if we now show that...' .

Apart from infinitival constructions, participial expressions are used quite frequently. While in the non-technical discourse participial constructions are commonly considered as abbreviated forms of finite clauses, this interpretation does not always hold for mathematical texts. In some cases participial constructions may, or have to, be given (indirectly) referential interpretation via the PF. In (45a) this interpretation is supported by the use of *Konjunktiv I*:

(45) a. Angenommen, U habe noch nicht diese Eigenschaft
'...let us assume U does not yet have this feature'

(A-4)

and in (45b) by the use of *Konjunktiv II*:

(45) b. *Angenommen*, es wäre $R \in H^*_{m+2}$
'let us assume that ...' .

(A-1)

The use of participial constructions is an individual choice of the author. Some authors prefer to use finite clauses instead, as illustrated in (45c and d):

(45) c. Wir nehmen an, (2) sei nicht erfüllt...
'we assume that (2) is not satisfied...'
d. Wir können ... annehmen, daß...
'we can assume that...' .

(A-10)

Since mathematical discourse is highly formalised and standardised (due to the deductive character of mathematical reasoning, (cf. Subsection 2.2.4)) some fossilised participial expressions function as a particular type of discourse connective and should not be interpreted in referential terms. This is illustrated by (46) below:

(46) *Zusammenfassend* erhalten wir nun mit Theorem 7, Folgerung 3 und Lemma 11 die folgende Aussage
'summarising, with theorem 7, proposition 3 and lemma 11, we obtain the following expression' .

(A-1)

The present participle in (46) is not interpreted as indirectly referential, i.e. the 1st participant of the predicate *erhalten* ('to obtain') is not interpreted as co-referential with the 1st participant of the PF of *zusammenfassen* ('to summarise'). The same non-referential interpretation applies to expressions such as *angenommen, daß* or *vorausgesetzt, daß* ('presupposing that'). They can be substituted by *wenn wir annehmen, daß* or *wenn wir voraussetzen, daß*. They can also be substituted by *wenn*. *Wenn*, however, is semantically empty and its only function is to express a particular (temporal or conditional) relation between other statements. *Angenommen daß* and *vorausgesetzt daß*, on the other hand, combine the relational function of *wenn* and the desired

semantics of a cognitive action of some sort, inherited from the matrix verbs they are derived from. Thus, in mathematical discourse they constitute a class of semantically non-empty relational words.

More often than free participles, we find participles used as attributes. We also find constructions that are passive in form (*Zustandspassive*) but must not be interpreted as passives since they do not correspond to any active clauses. Therefore they must be treated as simple relational-attributive constructions. Whether participles are to be considered as means of impersonal rhetoric (and interpreted via their PFs as indirectly referential) or simply as adjectives, depends on their semantics in the restricted context. This last condition is important since the restricted discourse domain may impose additional semantic and pragmatic constraints on the prototypical feature specification of the PF argument slots.

As expected, past participles (*Partizip II* - forms) are more readily used as potential means of indirect reference than present participles. This is because they are predicated of the 2nd argument of the PF of the matrix verb and therefore allow for the demoted 1st participant to be left out. Present participles (*Partizip I* - forms) are predicated of the 1st argument of the verb and consequently do not allow for its omission. However, in some cases it seems that the restricted context changes the prototypical feature specification of the arguments. In this way certain originally non-technical lexical items lose their prototypical meaning and become technical terms. To use them properly one has to learn their explicit definitions, where the new prototypical arguments (valid in the particular domain of communication) are specified. This explains why some predicates become *defective* in their technical use. They may have different PFs, with a different number of argument slots.

(47) Die Funktion ϕ ist unendlich oft differenzierbar, weil die Differenziation unter dem Integralzeichen *erlaubt ist*
'function ϕ is infinitely often differentiable because differentiation under the integration sign is permitted' .

(A-9)

The participial form *erlaubt* ('permitted') with the meaning illustrated by the above example, occurs only in the relational-attributive form, i.e. cannot be treated as derived from the standard PF of *erlauben* ('to

permit') with the prototypically human 1st participant omitted. The same comment applies to the expression *z ist abgeschlossen* ('z is closed') in (48), since it does not have the corresponding active form:

(48) Satz 2.1. Seien Z, P und N disjunkte, bezüglich 0 symmetrische Teilmengen von R mit den Eigenschaften:
(i) P und N sind offen;
(ii) Z ist abgeschlossen...
'theorem 2.1. let Z, P and N be disjoint partial sets of R, symmetric with respect to 0 and having following properties:
(i) P and N are open;
(ii) Z is closed...' .

(A-9)

Example (49) below shows that one noun phrase may contain both participial attributes having indirectly referential function and participial attributes lacking this function. In (49), *ausgewählt* ('chosen') must be related to its basic PF *auswählen* ('to choose') and linked with some sort of volitional human activity. However, this meaning is modified by the adverb *beliebig* ('any'/'arbitrary') which indicates that there is no need to identify the individual referent of the 1st argument. *Abgeschlossen*, on the other hand, does not evoke agentive interpretation.

(49) In [4] hat P. Levy charakteristische Funktionen konstruiert, die in endlich vielen, *beliebig ausgewählten abgeschlossenen* Intervallen ... verschwinden und außerhalb dieser Intervalle positiv sind
'in [4] P. Levy constructed characteristic functions which vanish in finitely many arbitrarily chosen closed intervals ... and which are positive outside these intervals' .

(A-9)

In this section we have presented the infinitive and participial constructions as used in German mathematical discourse. We distinguished between constructions that can be employed as means of indirect reference and those that require non-referential interpretation. This distinction is due to either a syntactic constraint (blocking of the 1st participant slot) or a semantic constraint (1st participant must be - HUMAN). In the following

subsection we consider to what extend the PF model applies to some nominal expressions in mathematical texts.

4.3.6 **Nominal Means of Indirect Reference via Predicate Frame**

Nominal style is one of the features commonly attributed to scientific discourse in general. In this subsection we discuss the use of nouns and adjectives as a means of avoiding direct reference to the participants in the communication.

Nouns which either derive from polyvalent verbs or share the same core semantics may be related to a specific number of arguments corresponding to the number of participants in an action/event described. Thus, we could say that the notion of valency might be extended to word classes other than verbs. Nouns which require certain complements or are associated with certain participant roles occur both in technical and in non-technical discourse. Technical discourse, however, exploits the indirectly referential potential of nominal expressions to a greater extent than would be possible in a non-technical (especially spoken) communication. Here are some examples of the heavily nominal mathematical discourse:

(50) Unser Ziel ist unter anderem ein neuer Beweis dieser Aussage. - Im Zusammenhang hiermit befassen wir uns in der vorliegenden Arbeit vor allem mit den folgenden beiden Sätzen, denen unabhängig vom obigen ... Satz ein Interesse zukommen dürfte
'our aim is, among other things, a new proof for this statement. in this context we occupy ourselves in this paper predominantly with the following two theorems which deserve interest independently of the above theorem...'
(A-4)

(51) Mit dem Nachweis von Satz 1 ist eine Vermutung von K. Stein ([22]) bewiesen
'with the proof of theorem 1, K. Stein's conjecture ([22]) is proved'
(A-4)

(52) Gegenüber den allgemeineren Überlegungen von IV sind im vorliegenden Spezialfall starke Vereinfachungen möglich
'contrary to the more general considerations in IV, in

this special case strong simplifications are possible'

(A-4)

(53) Im allgemeinen ist die Suche nach Klassenstrukturen E von G mit $l^i(E) = 1$ mit aufwendigen Rechnungen verbunden
'in general, search for class structures E of G with ... is connected wih laborious calculations' .

(A-11)

In the spoken discourse, the fragment quoted in (50) could take the following form:

(54) ...wir möchten aufs neue beweisen was hier gesagt wurde/deswegen befassen wir uns hier vor allem mit diesen zwei interessanten sätzen...
'...we would like to prove in a new way what was said here/therefore we are concerned here first of all with these two interesting theorems...' .

Some nominal expressions, such as *unter der Annahme* ('under the assumption'), *unter/bei Berücksichtigung* ('taking into consideration') or *unter Voraussetzung* ('presupposing') can be treated in the way free participles were treated in the preceding subsection. These are fossilised expressions that do not require any individual referential interpretation. We could explain this by the fact that in a restricted context they are permanently linked with a specific discourse role which is defined as 'one who performs the calculation'.

Deverbal adjectives with suffix *-bar* may also serve the purpose of indirect reference by their links with PF-slots of a matrix verb. Again, this cannot be seen as a general rule, since the indirectly referential property or potential of adjectives is determined by their specific meaning in the restricted context. Thus, e.g., adjectives such as *integrierbar* describe an inherent property of certain objects and do not necessarily refer to any real action performed on those objects by any real agent. For example, functions are *integrierbar* even if the actual procedure of integration was not (cannot be) carried out (e.g. when integrals cannot be found in a closed form).

Some other adjectives, such as e.g. *realisierbar*, *lösbar*, *aufzählbar* may have different interpretations according to what objects they are attributed to. For example in (55) and (56) they may be treated as simple adjectives, i.e. as expressing properties rather than referring

to possible actions:

(55) Sind k ein Körper mit $(k : Q^{ab}) < \infty$ und G eine endliche Gruppe, deren Kompositionsfaktoren zyklisch sind oder GAR-Darstellungen über k(t) besitzen, so *ist* G als Galoisgruppe über k *realisierbar*
'if k is a field with ... and G is a finite group whose composition factors either are cyclic or have GAR-representations over k(t), then G can be represented as Galois group over k'

(A-11)

(56) Einbettungssatz von Iwasawa: Ist k ein Erweiterungskörper von Q^{ab}, so *ist* jedes Einbettungsproblem mit auflösbarem Kern über k *lösbar*
'embedding theorem by Iwasawa: if k is an extension of Q^{ab} then each embedding problem with a soluble core is soluble over k' .

(A-11)

Indirectly referential interpretation applies to adjectives related to calculation procedures and techniques, such as e.g. *vertauschbar* (*kann vertauscht werden* - 'can be substituted'), *nachweisbar* (*kann nachgewiesen werden* - 'can be proved'). For these and other adjectives that allow for indirect reference, the 1st argument of the matrix PF is not associated with any specific individual referent and the construction requires a general reading.

Adjectives with the suffix *-bar* have comonly been treated as means of *Deagentivierung* in German. However, most instances of adjectives with *-bar* found in mathematical texts express properties of mathematical objects. Consequently, they cannot be considered as means of indirect reference in this specific communicative domain.

4.4 Other Means of Indirect Reference

4.4.1 Pronoun Shift

In the preceding section we discussed syntactic means of indirect reference such as the passive or infinitive constructions. In those cases the existence of an argument is inferred by reference to the prototypical features on the matrix PF. In the restricted context of scientific discourse, this type of indirect reference is possible for verbs related to the set of context specific discourse roles. In the contexts of scientific discourse such as those considered here, these are the predicates related to the transfer of knowledge and to cognitive actions in general. For these predicates, the existence and presence (immediate or remote) of all prototypical participants is assumed as necessary. Therefore, explicit reference to them may be omitted if this omission is allowed by the syntax. In the previous section, we have seen that the speaker may choose from a wide range of syntactic and lexical means of indirect reference to himself and to the audience. Most of the constructions considered so far can be used for self-reference as well as for reference to the audience.

In this subsection we point out that the speaker's choice of indirectly referring expressions is not accidental. We discuss the mechanism of pronoun shift, indicating rules and constraints that govern the use of pronouns.

Before beginning communication, the speaker has a full choice of means he can use to refer to himself. He may choose direct self-reference by using the 1st Person Singular pronoun *ich* (cf. Section 4.5 for details of the use of deictic pronouns), although this contradicts the impersonal rhetoric of science. Most naturally, he can use the generalised *wir*, considered as a neutral means of self-reference in scientific discourse. *Wir* used in science for indirect self-reference is different from the 1st Person Plural pronoun used in non-scientific communication, as was pointed out by Strawson [1959] (cf. Subsection 2.3.2). The generalised *wir* is not a proper Plural pronoun, since it does not have a corresponding Singular, and it is not a proper 1st Person pronoun since it can be used for referring to the audience only (i.e. excluding the speaker). Although it does not happen very often in practice, the author might also use the indefinite personal pronoun

man or impersonal passives for self-reference (supported by local and temporal deixis). In our corpus one paper was written in this manner.

The initial choice, even if influenced by science specific rhetoric and a general desire to be objective i.e. impersonal, is still *speaker dependent* and *individual*. Although the speaker has a free first choice, his further steps, i.e. the choice of the way he refers to the immediate audience, to the individual reader or to shared knowledge are determined by how the self-reference is achieved. Let us now consider what different options are available after different initial choices.

If the author's choice for self-reference is the deictic *ich*, a direct reference to other participants in the communicative situation and to its time and place is preferred. This means that the immediate audience will be addressed by *Sie* and the speaker and audience together will be referred to by *wir* (i.e. *ich* + *Sie*). Only the general, ideal audience, which is a personification of the entire knowledge on the subject, will be referred to by means of impersonal constructions. In the spoken communication, this convention does not have to apply to the entire discourse. However, any change in the established reference pattern must be made explicit. We leave out here detailed discussion of direct self-reference with the 1st Person Singular pronoun *ich* and its implications. This point is further analysed in Section 4.5 and examples are given.

If the generalised *wir* is chosen as the way of the speaker's self-reference, the same form can still be used to refer to the speaker and the audience together. The change of referential scope is often signalled, either by the fact that the predicate is associated with different discourse roles or by means of local and temporal deixis. This can be illustrated with the following passages from the spoken discourse.

Example 4.4

> ...also die menge a besitzt innere punkte und der durchschnitt beider mengen ist leer/nach dem trennungssatz den *wir jetzt aufgeschrieben haben*/das ist der trennungssatz nach Eidelheit/ *kann man* die beiden mengen *trennen*/mit einer hyperebene trennen/also nach Eidelheit/*wo sind wir*?/hier/satz von Fenchel/ das ist jetzt nun die aussage/ja/hier/*soweit sind wir gekommen*/...folgendes gilt/x eins angewandt auf ypsi.../oder

ypsilon angewandt.../*das wollte ich ... schreiben*/ypsilon angewandt auf x.../*hätten wir* also.../beta gleich null *können wir weglassen* und dann steht hier nun ... /*jetzt wollen wir uns überlegen* daß das hier ein widerspruch ist/.../*jetzt wollen wir sagen* dies ist ein widerspruch/den *wollen wir uns doch gemeinsam überlegen*/das *haben wir uns auch schon überlegt*/.../wieso geht das jetzt nicht?/*jetzt haben wir* punkte aus dem endlichkeitsbereich/...das ist vielleicht etwas knapp hier/der satz hier.../aber...*überlegen müßte man* eventuell auch noch mal.../*den satz genau ausführen*/obwohl er geometrisch natürlich ganz leicht ist...

(B-4)

In the discourse fragment above *wir* is used in two different functions. The first is the speaker's indirect self-reference in the phrase *nach dem trennungssatz den wir jetzt aufgeschrieben haben*. The self-referential interpretation is supported by the pragmatic link relating the 1st participant of *aufschreiben* ('to write down') to the speaker.

In the same fragment *wir* is also used for direct reference to the speaker and the audience together in the phrase *den (widerspruch) wollen wir uns gemeinsam überlegen*. This interpretation is explicitly signalled by *gemeinsam* ('together').

The speaker uses also direct self-reference, i.e. the pronoun *ich*, when he refers to his own mistake - *das wollte ich... schreiben*.

Impersonal constructions are used to distinguish between reference to the speaker or the speaker and the audience together on the one hand, and the body of general mathematical knowledge on the other hand. This knowledge is neither subjective nor is its validity dependent on an individual speaker. In example 4.4 the indefinite personal pronoun *man* is used contrastively to the *wir*-clauses. Further examples of the *man*-clauses from the discourse fragment by the same speaker are given below:

Example 4.5

...also wenn diese beziehung gilt dann *sagen wir* dann sind die aufgaben schwach dual und dual/.../das *nennt man* ja dual oder stark dual/.../ das heißt dual und dann *unterscheidet man* noch wenn die beiden aufgaben dann noch *lösbar sind*/dann *nennt man* dieses noch dann stark/das ist ja aber sekundär jetzt/diese

unterscheidung/*für uns* jetzt ist das wichtigste wenn diese beide/daß die beiden gleichen wert .../das bedeutet wenn *wir* die eine aufgabe *gelöst haben* und den wert *berechnet haben* dann *haben wir* zugleich auch die duale aufgabe/zumindest den wert der dualen aufgabe auch schon *bestimmt*/.../also diejenigen die sich etwas mit der linearen programmierung oder sonst *beschäftigt haben*/.../dann *werden Sie feststellen* daß gerade dadurch daß *man* die duale aufgabe *hat*/.../überhaupt erstmal, so was wie simplex algorithmus *definieren könnte*/denn *man braucht* immer wenn *man rechnet* ... ein achtungskriterium/dann *möchte man wissen ist man schon soweit* mit der rechnung daß *man* damit *aufhören kann*/daß *man* ja die vorgegebene genauigkeit schon bereits *erreicht hat*/das ist eine sehr wichtige fragestellung...

(B-4)

Spoken discourse always contains some deictic elements. A mathematical paper, on the other hand, can be written in a fully 'impersonal' style, i.e. without even the generalised *wir* as a means of indirect self-reference. Nevertheless, a distinction between actions attributed to the author and the reference to the audience or to general knowledge can still be made. A special type of deictic expression is used to support the interpretation of certain indirectly-referential expressions as referring to the author. These are the *text-deictic* elements, related to the structure of the text itself (further discussed in 4.4.2). Below we give some examples taken from a paper (text A-2 in our corpus) where neither the *ich*- nor the *wir*-form of the author's self-reference was used.

(57) a. Um dies aufzuklären, soll **im folgenden** die Funktionenfolge (σ_n), die gegeben ist durch ... untersucht werden
'to explain this, the sequence of functions (σ_n), given by ... is investigated in the following'

b. **Zum Abschluss** sei noch eine vierseitige Pyramide erwähnt, bei der sich alle Kantenwinkel elementar berechnen lassen
'finally a four-sided pyramid will be mentioned, in which all angles ... can be easilly calculated'

c. Die möglichen regulären Pyramiden mit dieser Eigenschaft wurden **in Kapitel 2 diskutiert**
'the possible regular pyramids with this property were discussed in chapter 2'

d. **Zunächst** seien die regulären Pyramiden betrachtet, bei denen alle Kanten gleich lang sind
'first, regular pyramids with all edges equally long shall be considered'

(A-2)

(57b and d) illustrate a very special use of *Konjunktiv I*. The predicate *betrachten* ('to consider') in the restricted context of mathematical discourse does not have any constant link with discourse referents. It can be associated with the author as well as with the audience, or with their common activity. Since in the paper considered neither *ich* nor *wir* was chosen as means of the author's self-reference, the remaining options are passive and infinitive constructions. When used in the *Indikativ* mood, they would be open for either self-referential or general interpretation. The use of the *Konjunktiv I* disambiguates the expression. Being a departure from the neutral *Indikativ* mode, it signals the reference-switching and consequently supports the (semantically marked) self-referential interpretation (cf. further discussion on the reference supporting function of the mood in Subsection 4.4.2).

In the same text (A-2), the reference to the audience is signalled by the use of periphrastic imperatives with the *Konjunktiv I* or with modal verbs in *man*-clauses. The use of the *Konjunktiv I* distinguishes *man*-clauses used to address the immediate audience from the indefinite personal *man* in its general function. *Konjunktiv I* may be seen as a formal indication of the reference-switching. However, the reader is probably able to distinguish between actions that he is asked to perform and general statements. This distinction is based on the link between PFs of certain verbs and the set of context-specific discourse roles. At the uppermost level of indirect reference, i.e. in statements related to the general audience and in statements describing properties of mathematical objects, passives without deictic elements and infinitive constructions are used.

The pattern of reference naturally changes when a mathematical paper is written by two (or more) authors. In this case the pronoun *ich* cannot

be used as a direct self-reference since the paper is a joint production. Direct self-reference of the authors is taken over by *wir*, as illustrated by the fragment below:

Example 4.6

> *Wir wollen nun versuchen*, ein Ergebnis analog zu 3.4 für Mannigfaltigkeiten *zu beweisen*. ...
> Es gilt
> Satz 3.5 1) X' ist Poincaré-Komplex.
> 2) X'/Z_r kann als einfacher Poincaré-Komplex angenommen werden.
> 3) Das Spivaksche Normalenbündel $\overline{\upsilon}: X'/Z_r \to GB$ liftet zu B Cat. ...
> *Wir fixieren* eine Liftung... *und erhalten* ... .
> *Also brauchen wir nur festzustellen*, wann ... .
> Für diese Forderung *betrachten wir* eine explizite rationale Äquivalenz ... .
> *Benutzen wir* den natürlichen Isomorphismus (im glatten Fall *benötigen wir* hier Bedingung P4) ... so folgt offenbar, daß ...
> *Wir erhalten nun*...

(A-7)

Self-reference can also be achieved in an indirect way, e.g. with passives accompanied by some deictic elements (in the example below it is the use of the Future Tense:

(58) Dies *wird* in einer späteren Arbeit *behandelt werden*
'this will be considered in a future paper' .

(A-7)

However, *wir* cannot be used in its non-deictic (general) function any more. This function is taken over by *man* and other means of indirect-reference, as illustrated below:

Example 4.7

> Bezeichnet $\epsilon : K[e] \to K$ den Augmentations-Homomorphismus ($\epsilon(e) = 0$), so *läßt sich* vermöge der angegebenen Isomorphismen die Gysin-Sequenz folgendermaßen *darstellen*: ...
> Nun *muß* noch die multiplikative Struktur der Kohomologie-Ringe *berücksichtigt werden*. Folgendermaßen *gewinnt man* ... . Dann *definiert man* ... .

Beweis von Lemma 2.5. Zunächst *konstruieren wir* durch Angabe von Erzeugern eine geeignete Unteralgebra... und *bestimmen* ... eine Bilinearform... .
(a) m = 2*l*. *Wähle man* einen maximalen ϕ_m-isotropen Unterraum K^l... . Zum Beweis von (a) *kann man setzen*: ...

(A-7)

The mechanism of pronoun shift described and illustrated in this subsection is based on a hierarchy principle. Direct reference is the first and most natural choice in most contexts.

If, however, for some reason, e.g. due to the impersonal rhetoric of science, this choice is abandoned, the reference system starts at the next level. In German scientific discourse, for instance, this would be the generalised *wir* used for self-reference. The author can make the initial choice above the level of definite pronouns and use only the indefinite personal pronoun *man* or passive and infinitive constructions as means of self-reference. Then, the distinction between self-reference and reference to other participants in the communication is supported either by the link between the PF of a lexical predicate and specific discourse roles or by all sorts of deixis. These rules are language- and context-specific (cf. e.g. Laberge & Sankoff [1979] for a discussion of the mechanism of pronoun shift in Montreal French).

The following (discourse opening) fragment of a mathematical paper illustrates various types of indirectly referential expressions used without affecting definite personal reading.

Example 4.8

1. Einführung
Die syntaktisch beschränkte Rekursion *wurde in [1] eingeführt, um* gewisse Klassen zeitbeschränkter Turingmaschinen ... *beschreiben zu können*. In anschließenden Untersuchungen, z.B. [3,4], hat sich diese Operation als sehr geeignet zur Beschreibung der inneren Komplexität von Funktionsklassen erwiesen. So *ist* z.B. das klassische Problem PTIME = PTAPE *formulierbar* in der Rekursionstheorie als Frage nach der Gleichwertigkeit der ... . *Ausgehend* von der üblichen syntaktisch beschränkten Rekursion **werden wir** neue Operationen **einführen**, indem **wir** die Anzahl der Rekursionsschritte **reduzieren**. ...

2. Definitionen

Zuerst **wollen wir** für einige Funktionen Abkürzungen **festlegen** ...

Wir führen nun die syntaktisch beschränkte Rekursion m-ter Stufe **ein.**

(A-1)

In the above fragment *wir* is used for the author's self-reference. This interpretation is supported by the adverbials *zuerst* ('first') and *nun* ('now'). The present participle *ausgehend* is also interpreted as referring to the author. The agentless passive *wurde eingeführt* is given a definite reference interpretation because of the locative phrase *in [1]* which points to a specific idividual referent (not identical with the author). The construction *ist formulierbar* has a general reading and is equivalent to *kann formuliert werden* or *läßt sich formulieren*.

The hierarchical and systematic nature of the pronoun shift in scientific discourse facilitates the interpretation of the indirectly referential expressions. Once the initial choice is made, i.e. once it is decided and made explicit what has been chosen as a means of the author's self-reference, the interpretation of other indirectly referential expressions used in a given restricted context is to a large extent predictable. A difference in the way this mechanism works in the written and spoken discourse is discussed in Chapter 5 (Subsection 5.1.1).

4.4.2 **Deixis as Support of the Reference Interpretation**

So far we have looked at syntactic means of indirect reference and the mechanism of pronoun shift. We have seen that one and the same syntactic construction or even one and the same pronoun may fulfil a number of different referential functions. The interpretation of reference depends on the discourse roles associated with the predicate and on the overall referential set-up chosen by the speaker/author (e.g. on the initial choice of the means of self-reference, spoken versus written discourse, etc.). This interpretation is facilitated by lexical and non-lexical deictic means, such as local and temporal indicators, as well as by Tense and Modality. In this section we discuss the use of deictic elements in scientific discourse, concentrating on their reference-supporting and reference-switching function. (For a comprehensive presentation of pronominal and other deictic elements in German see Braunmüller [1977].)

In Subsection 2.3.1, we indicated that, according to the impersonal rhetoric of science, all *egocentric particulars* should be avoided, i.e. not only the author's direct self-reference but also any direct reference to the place and time of communication. Mathematicians usually view mathematical knowledge as a body of proven theorems. As such mathematical facts are *a-temporal* (i.e. always true) and *a-spatial*. They do not need to (or even cannot) be related to any *time* or *place*. Scientific activity in mathematics, on the other hand, like all human activities, happens in a *situation* , i.e. it has location in time and space (and consequently in a certain culture). Mathematical papers as well as the spoken mathematical discourse (e.g. a lecture) contain statements about facts of both types mentioned above, i.e. theorems (and other *primary statements)* and descriptions of operations one has to perform to prove them etc. (*meta-statements*). Facts of the first type are seen as time- and space-independent and expressed in a *non-indexical mode* (cf. 2.3.1). But since facts of the second type are related to deictic categories, their description may contain deictic, *indexical* elements. Since we are concerned here with reference to human participants in the communication, we are interested only in the second type of statements, i.e. in *metastatements*. Moreover, the impersonal rhetoric of science applies to metastatements only. Mathematical facts are a-personal by themselves, i.e. cannot be presented in a personal way.

In the case of a mathematical lecture, deictic elements cannot be completely avoided. The speaker and the audience share the same immediate situational context and deictic expressions (such as e.g. *hier* ('here') when pointing to objects or formulae on the blackboard) are often the most economical ways of reference. In written discourse, *here* and *now* are also used but in most cases have a different function. The interaction between the author and the audience (the reader) is *delayed* (cf. Subsection 2.2.2). Consequently, the participants in the communication do not share the same situational context and *here* and *now* cannot be used in their *situation-deictic* function any longer. They become *text-deictic*, i.e. they refer to certain points in the narration itself, or to the discourse as a whole (often *here* is used contrastively to other *communicative situations* i.e. other papers). In spoken discourse, the deictic and the narrative functions of time- and place-adverbials are often collapsed. Then the deictic interpretation is preferred. Discourse fragments below illustrate the use of elements of local and

temporal deixis in written and spoken mathematical discourse.

Example 4.9

> Ich will *hier* kurz den Beweis für r = 1 angeben, um den Einsatz der Bedingungen (G), (A) und (R) vorzuführen. ... Nach (R) ist K/k ein rationaler Funktionenkörper, so daß *jetzt* die Behauptung des Einbettungssatzes im Fall r = 1 aus dem Hilbertschen Irreduzibilitätssatz folgt
>
> (A-11)

Example 4.10

> Wenden wir uns *nun* den Klassen H_m^* zu...
> Wir wollen *nun* für die Klassen H_m ($m \geq 2$) eine zusätzliche Charakterisierung angeben
>
> (A-1)

Example 4.11

> Da das Hauptergebnis aus [4] wesentlich in den Beweis von Satz 2 eingeht, erscheint es nützlich, einige Bemerkungen *hierüber* anzuschließen. Es handelt sich *hier* um die Äquivalenz des (normalen) komplexen Raumes im Sinne von Behnke, Stein einerseits und im Sinne von Cartan, Serre andererseits
>
> (A-4)

Example 4.12

> ...also dies ist wie gesagt/hoff' ich jedenfalls so/gut zu lesen/.../also das sind die wichtigsten sätze über die konjugierten funktionen... /verbindung zwischen ... soll damit *jetzt hier* charakterisiert werden/... ich wollte *dann später* diesen satz auch in den text noch integrieren deshalb habe ich die nummerierung.../also *hier* fängt dieser satz an/*hier* an.../ diejenigen die skript haben brauchen *jetzt hier* nicht mitzuschreiben.../ .../wie gesagt also ich möchte *jetzt* nicht voraussetzen daß sie denn das.../schon das skript.../dann schon gelesen haben/also wir benutzen *nun* nur das skript so wirklich nur als ergänzung/und *da* sage ich ihnen ja nur paar seiten die sie *jetzt*.../die *zu dieser vorlesung jetzt* gehören/die sie sich angucken sollen und *jetzt*/auch *jetzt*/.../so sind auch *jetzt* diese als ergänzung zu verstehen...
>
> (B-4)

Example 4.13

...ja dann sind wir fertig/ne?/so/*jetzt* wollen wir sagen wir haben einen operator/dissipativ/*nun* das könnte unser letzter teil für *heute* sein...

(B-1)

Example 4.14

...*jetzt* wollen wir mal sehen periode sechs zwei/sechs zwei/das ist ja *nun* eine andere periode/das macht er (i.e. Gauss - M.S.) auch/.../so ja wie macht man *jetzt* diese?/...*jetzt* könnten wir das natürlich/*jetzt* ist.../das lambda ist die zwei/das geht also *jetzt* los *hier* mit zwei plus.../zwei mal.../wie sollen wir das machen?/.../na ja *hier hinten* steht das einfach.../die frage ist doch/die wir *eben* hatten/ist wie kriegen wir denn andere verschiedene perioden *hier*?/*hier* hat er die eins genommen.../*hier* hat er die zwei genommen/welche lambdas müssen wir denn nehmen um alle perioden zu berechnen?/.../ das ist ein alter trick aus der allgemeinen zahlentheorie/und dazu muß man das produkt zweier perioden ausrechnen/und das war lange zeit glaube ich sehr schwierig für den Gauss/und ist auch *bis heute* nicht ganz einfach/aber das macht er eben mit seiner merkwürdigen bezeichnerei/*hier in dem artikel dreihundert fünfundvierzig*/ausgesprochen übersichtlich/*hier* rechnet man das produkt von zwei perioden/.../gut/den rest können wir dann *am montag* machen/

(B-2)

We note that in spoken discourse direct, situation-deictic use of *here* and *now* is licensed. *Jetzt hier* can be used contrastively to *dann später* as illustrated in example 4.12. The reference of *hier* can also be made explicit as in *hier in dem artikel dreihundert fünfundvierzig* or *hier hinten* in example 4.14. On the other hand the narrative, text-deictic function of *here* and *now* in mathematical papers is an expected consequence of the self-contained character of written scientific discourse. Although scientific knowledge may be seen as independent of real time and space, its presentation has a certain structure, organisation and sequential order. It is therefore quite natural to use the otherwise unemployable *now* and *here* to refer to that structure or sequence.

Apart from lexical means of deixis, verb categories such as Tense and Mood may be used to support specific reference interpretation or to

signal reference switching. The category of Tense is deictic. The choice of grammatical tense is speaker dependent and reflects his 'location' in real time and his way of ordering the events. In scientific discourse the temporal order of events is largely replaced by their causal dependency which does not involve the time factor. Thus, the General Present Tense is a preferred convention. Any departure from the Present Tense signals that the statement requires interpretation which goes beyond the *restricted context* (i.e. it should not be assigned interpretation according to the set of discourse roles assumed for the context etc.). To facilitate the interpretation, clauses involving tenses other than Present usually contain either some direct reference to the participants or some indication of time or place which helps to identify participants referred to indirectly. This is illustrated by the examples below.

(59) Der Begriff des quasikomplexen Raumes *wurde von K. Stein in [22] eingeführt*, um ... Räume z_1 ... kurz beschreiben zu können
'the concept of the quasi-complex space was introduced by K. Stein in [22] to describe in a short way ... spaces z_1 ...'

(A-4)

(60) Mit Hilfe von Zusatz 1 *konnte Belyi in [2] unter anderem zeigen*, daß alle klassischen einfachen Gruppen ... als Galoisgruppen ... vorkommen
'using condition 1, Belyi could show in [2] among others, that all classical simple groups ... are Galois groups...'

(A-11)

(61) Die syntaktisch beschränkte Rekursion *wurde in [1] eingeführt*, um gewisse Klassen zeitbeschränkter Turingmaschinen ... beschreiben zu können
'the syntactically restricted recursion was introduced in [1] to describe ... certain classes of Turing machines with time limit'

(A-1)

(62) Die Bedingungen in Satz (1.0) können voraussichtlich abgeschwächt werden, wenn ... Operationen zugelassen werden. *Dies wird in einer späteren Arbeit behandelt werden*

'conditions in theorem (1.0) can probably be weakened when ... are permitted. this will be considered in a future paper'

(A-7)

(63) *Häufig werden wir* die Tatsache *benutzen*, daß die ... Λ-Moduln eine ... Serresche Klasse bilden
'we shall often use the fact that the ... Λ-modules constitute a Serre-class'

(A-7)

In (59)-(61) the Past Tense is associated with explicit reference to the participants involved. In (59) and (60), proper names are used. In (61) the locative phrase *in [1]* points to the agent. In (62) and (63) the Future Tense (*Futur I*) is used. These two examples illustrate two types of self-reference: indirect reference via the PF in (62) and direct in (63) (NB the text A-7 is written by two authors).

We note that the Past Tense in scientific discourse may be used to refer to any of the discourse participants. The use of the Future Tense, on the other hand, is in most cases connected with the speaker's self-reference or his reference to the audience and himself together. This dependency may be related to the distinction between past events (facts) and future events (assumptions or hypothetical facts). As we pointed out in Subsection 2.2.2, scientific discourse obeys the Gricean maxim of quality - *do not say what you do not have evidence of*. Therefore, we may assume that the author talks only about those future events that are certain for him. These are mostly events which he *controls*, i.e. in which he himself is involved.

The other speaker dependent verb category is Mood. The neutral choice is the indicative, and most of the mathematical discourse, over 90% in the written discourse, involves the indicative. Details of a frequency analysis of verb categories in German and French mathematical discourse are presented in Stroińska & Zamojska [1985] and in Stroińska [1987-forthcoming]. In German, the possible formal departures from the neutral *Indicativ* are: *Imperativ*, *Konjunktiv I* and *Konjunktiv II*. The *würde*-form is not treated separately in this thesis.

These three morphologically distinctive moods, as well as some other modal elements used in mathematical discourse, fulfil two major functions which we could label as *voluntative* and *conditional*.

The conditional interpretation results from the use of the *Konjunktiv II* form of the main verb (or *Konditionalis* i.e. *würde* + infinitive of the main verb) as well as from the use of the modal verbs, often also in *Konjunktiv II*. All these forms may signal the hypothetical, conditional status of the statement, and reveal the existence of a subject who makes the judgement and presents his *subjective* point of view. Some examples of conditional expressions are given below:

(64) Wir nehmen nun an, *es wäre* $Q \in L_3^*$. Wegen Lemma 8 *gäbe es* dann ein r, so daß zu jedem n Polynome P_i^j... existieren...
'now we assume, there were ... . then according to lemma 8 there would be an r, such that for every n there exist polynomials...'

(A-1)

(65) Aus J, R folgt D. ... Aus ... oder ... *würde folgen*:...
'from J, R follows D. ... from ... or ... would follow:...' .

(A-12)

Frequency analyses indicated that *Konjunktiv II* and *Konditionalis* are used rather rarely in mathematical discourse in general. In Stroińska & Zamojska [1985] it was shown that these two forms together covered less than 1% of the investigated corpus of mathematical texts, although this value may differ for different branches of mathematics.

The Mood used more often (over 6% in the frequency analysis referred to above) is *Konjunktiv I* in its *voluntative* function, characteristic of mathematical discourse. We illustrate the use of voluntative *Konjunktiv I* (the so called *heischender Konjunktiv*) with the examples below:

(66) Bemerkungen. *Sei* M^m eine einfach-zusammenhängende geschlossene Mannigfaltigkeit
'remarks. let M^m be a simply connected closed manifold

(A-7)

(67) Satz 3.2. G *operiere* frei auf X aber trivial auf ... . Dann gibt es...
'theorem 3.2. let G operate freely on X but trivially on ... . then there is...'

(A-7)

(68) Für den Rest dieses Paragraphen *seien* X^n und Y^n geschlossene n-dimensionale Mannigfaltigkeiten. S^1 *operiere* ... auf Y^n und X *sei* ... homotopieäquivalent zu Y. *Sei* r eine Zahl für deren Primteiler P1, P2 und P3 gelten. Schließlich *werde* X' wie in 3.4 *gewählt*
'for the rest of this paragraph, let X^n and Y^n be closed n-dimensional manifolds. let S^1 operate on ... Y^n and let X be ... homotopy equivalent to Y. let r be a number for the prime divisor of which P1, P2 and P3 are satisfied. Finally, let X' be chosen as in 3.4 '

(A-7)

(69) Grundannahme: *Gegeben sei* eine aus involutorischen Elementen erzeugte Gruppe..., die den folgenden Axiomen genügt:...
'basic assumption: let a group be given which is generated from involute elements and which satisfies the following axioms:...'

(A-12)

(70) *Es seien* X eine Zufallsgröße und f(t) ihre charakteristische Funktion
'let X be a random variable and let f(t) be its characteristic function'.

(A-9)

In the examples above, *Konjunktiv I* indicates the voluntative character of the statement and, in a sense, the creative nature of mathematical activity. Using *Konjunktiv I*, the author *defines* certain objects or their properties. By this act of defining or stating the properties, mathematical objects are 'brought into being' and can be further described and investigated. The results of this investigation hold only if the initial requirements on the object, spelled out by the author as a theorem, are met. This creative element in mathematical activity is naturally associated with the author in the case of a mathematical paper presenting original ideas. If an analogous construction is used in spoken discourse, where the speaker presents concepts introduced by somebody else, the volitional element in the interpretation of *Konjunktiv I* would most probably be associated with the speaker. In this case, it is the control over the presentation of the concepts rather than their creation.

However, we must note that the *Konjunktiv I* form of theorems in mathematics has become a rhetorical standard. As such it is normally not given a referential interpretation. We observed a similar development in the case of the fossilised participles discussed in Subsection 4.3.5. From a purely linguistic point of view, *Konjunktiv I* must be treated as a departure from the routine indicative mood. This departure points to the creative element in the act of defining (the same construction with the indicative would be a *description*, not a *theorem*). As such, it could be treated as a form of the author's indirect self-reference. We believe, however, that, due to the highly formalised nature of mathematical discourse and looking at this phenomenon synchronically, *Konjunktiv I* simply signals the special status of theorems and distinguishes them formally from other parts of mathematical discourse.

In non-technical communication *Konjunktiv I* is mainly used in Reported Speech (*Indirekte Rede*). There, it signals that the speaker is merely reporting what was said by someone else and does not take any responsibility for the correctness of the statement (i.e. a distinction must be drawn between normal language use and quotations or mention of someone's words). By using *Konjunktiv I* (which is not obligatory in the Reported Speech in German) the speaker may suggest that he distances himself from the statement he repeats, or simply doubts that what was said is true. We could expect that this interpretation is not a desirable one in scientific discourse since it clearly reveals the author's subjective point of view. Indeed, in the corpus we looked at, no instances of *Konjunktiv I* were found in Reported Speech. This, however, cannot be generalised, since *Indirekte Rede* with *Konjunktiv I* is likely to occur in, for instance, essays on the history of mathematics.

Konjunktiv I in mathematical discourse fulfils yet another important function. It is used with the subject *man* as a periphrastic form of the imperative:

(71) *Man wähle* nun $\alpha \in H^2(B;Z) = [B;BS^1]$, eine Klasse, die ...
auf ein Vielfaches von e abgebildet wird...
'now one should chose ... a class which ... is mapped onto a multiple of e ...'

(A-7)

(72) *Man beachte*, dass sie ausser von der Wahl des Parameters h auch von der ebenfalls willkürlichen Normierung (2) abhängen
'one should note that they depend not only on the choice of the parameter h but also on the arbitrary standardisation (2)'

(A-2)

(73) Als Beispiel hierzu *betrachte man* etwa ...
'as an example for this one should consider, say,...'

(A-4)

(74) *Man vergleiche* hierzu auch [4], Seite 250, Satz 2
'one should compare here also [4], page 250, theorem 2'

(A-4)

(75) *Man habe* vor Augen, daß...
one should bear in mind...'

(A-4)

(76) ...und dieses Verfahren *wiederhole man* bis man t erreicht...
'and one should repeat this procedure until one reaches t...' .

(B-3)

In the examples above, *Konjunktiv I* also has to be interpreted as having a *voluntative* function. Despite the common voluntative reading, there is a difference between *heischender Konjunktiv* in theorems and the periphrastic imperative constructions with *man*. Firstly, they involve predicates from two distinct semantic classes. As has already been pointed out, theorems, as primary mathematical statements, are by definition a-personal. Consequently, they involve either *relational verbs* or predicates that (at least in the restricted context of mathematical discourse) do not have prototypically human participants. The *man*-clauses, on the other hand, are possible only for predicates related to human participants. Consequently, the subject *man* must be interpreted as *personal*. The second difference relates to function. While *Konjunktiv I* in theorems signals the special status of a statement, the periphrastic imperative may be interpreted as a reference to the audience (inclusive or not). The *Konjunktiv* in (71)-(76) signals the *reference-switching*, from the general interpretation of *man* to the reference to the audience (or the audience and the author together).

Modal verbs may also fulfil the same function, as it is illustrated in example 4.15 below:

Example 4.15

> ...und *man nehme* einen erzeuger und/also das/das ist klar/also der zweite fall/k sei unendlich/dann *muß man* etwa wie folgt *argumentieren*/ja also den körper von da oben den brauchen wir noch/also wir machen folgendes/also wir setzen voraus .../.../jetzt *muß man sich* folgendes *überlegen* ...
>
> (B-3)

In the discourse fragment above the *man*-clauses are used contrastively to the *wir*-clauses. The *wir*-clauses may be interpreted directly as referring to the speaker and the audience together. We may note that the indirectly referential *man* could also be used in this function. The periphrastic imperative with *man*, however, is pointing to the audience. The audience is *instructed* to follow certain algorithms in order to achieve a formerly specified goal. This form of the imperative could be labelled as *didactic*.

In this section we have discussed personal, local and temporal deixis in mathematical discourse and deictic categories of the verb. Taking the deictic elements as supporting the interpretation of reference, we have analysed these together with certain prototypical features of predicate semantics and with pragmatic constraints on language use in the restricted context of scientific discourse. Only when all these aspects are brought together can we give mathematical discourse an appropriate reference interpretation.

4.5 Directly Referential Use of Deictic Pronouns

4.5.1 First Person Pronouns

In the majority of cases the speaker's self-reference in scientific discourse is achieved in an indirect way. There are instances of the 1st Person pronouns *ich* and *wir* used as directly referential. Although we find directly referential 1st Person pronouns both in written and in spoken mathematical discourse, they differ in their stylistic value. In this section we comment on their use and on some principles that govern their distribution.

The impersonality of mathematical rhetoric is a stronger imperative in written discourse and the Plural pronoun *wir* functions there as a neutral way of self-reference of the author. Therefore, we encounter the pronoun *ich* in written mathematical texts only in exceptional cases. In our data from spoken discourse, on the other hand, there are numerous occurrences of *ich*. The immediate situational context and the fact that the speaker is facing the real audience make it possible to use all sorts of directly referential deictic expressions.

In scientific discourse we find expressions such as *here* and *now* in two different functions. They can be used as 'indirectly' referring to the narrative structure (cf. Subsection 4.4.2) or as directly referring to the situation of communication. Also the 1st Person Plural pronoun *wir* is used as directly and indirectly referential and we comment further on its directly referential use at the end of this subsection.

If the 1st Person Singular pronoun *ich* occurs in mathematical discourse, then, unlike other deictic elements, it has only one function, i.e. it is used by the speaker to refer to himself. In the set of written mathematical texts that we analysed, there are few occurrences of *ich*. The use of the 1st Person Singular pronoun is obviously considered as contradicting the rhetoric of science. In older texts, if *ich* was used (except in introductions), one of the possible justifications for its use could be the assumption that the speaker for some reason did not identify himself with the community of mathematicians. (This explanation has been indicated to me by Professor Hilger Wolff from the Department of Mathematics, Christian Albrecht University in Kiel, who also suggested a possible source of examples for direct self-reference with *ich* in written mathematical discourse.)

Such an outsider in the mathematical community of his time was Edmund Landau, a 20th century German mathematician who, for a variety of reasons, did not identify with his milieu. In the introduction to his *Grundlagen der Analysis* [1930] p.VII, he wrote that his book was meant as a concession "an die (leider in der Mehrheit befindlichen) Kollegen, welche meinen Standpunkt in der folgenden Frage *nicht* teilen". In his writings, Landau distinguishes between his own statements or proposals, for which he uses forms of direct self-reference, i.e. *mein* or *ich*, and statements about what he assumes and accepts as general mathematical knowledge. Statements of the second type are expressed by means of impersonal constructions, with an indirectly referential *wir* or without any overt reference to acting humans at all.

Introducing the directly referential pronoun *ich* into discourse perspective licenses a more direct system of reference in general. Thus, other directly referring expressions (first of all proper names and forms of addressing the audience directly) also occur in the text. The style becomes more 'personal'. Let us consider a fragment of Landau's writing in more detail. The following passage is taken from the beginning of his [1923] paper:

Example 4.16

> Es sei U(n) die Anzahl der Zerlegungen von n in zwei Quadrate,
>
> (formula).
>
> *Herr Cramér* bewies für jedes $\epsilon > 0$
>
> (formula)
>
> wo
>
> (formula).
>
> *Ich* werde die Cramérsche Methode vereinfachen und zu einem Beweise des neuen Satzes
>
> (formula)
>
> führen. (A-6)

The Plural form *wir*, commonly considered as a neutral way of the author's self-reference in scientific discourse, was rejected by Landau, possibly because he felt that no other mathematician adopted the same position. Thus the indefinite general *wir* could no longer be considered as neutral in that specific context.

However, when the argument develops and the author arrives at conclusions that logically follow from the assumptions, he uses impersonal constructions as in (77)

(77) Im Falle $M^2 \leqslant y$ *ist* hiermit (2) *bewiesen*
'in the case of $M^2 \leqslant y$, (2) is thus proved' .

Since the proof was logically derived, its truth is no longer dependent on the author's subjective point of view. A proven theorem belongs to the body of accepted mathematical knowledge and as such it must be expressed in a distinctive way, i.e. not as speaker dependent.

In modern mathematical writing, a more personal, individual style is no longer an exception. Illustration is given in the passage 4.17 below.

Example 4.17

> Mit Hilfe von Zusatz 1 *konnte Belyi* in [2] unter anderem *zeigen*, daß alle klassischen einfachen Gruppen ... als Galoisgruppen regulärer Körpererweiterungen über $Q^{ab}(t)$ vorkommen. ... Die Körpererweiterungen N/k(t) ... weisen Symmetrien in der Verzweigungsstruktur auf. Dies *nutze ich* für ein schärferes Rationalitätskriterium *aus*, und zwar hier der einfacheren Formulierung wegen nur für s = 3. Dazu *schreibe ich* ... und *definiere* ... .
>
> Dann *erhält man* durch die Operation der erzeugenden Elemente der S_3:... eine Operation der Elemente ... (*siehe* [11], Zusatz 3.5 bzw. [12], Zusatz 6.3). *Bezeichnet man* die Anzahl der Bahnen unter diesen Operationen mit ..., so existiert wieder ... .
>
> Mit Folgerung 2b) *läßt sich* zum Beispiel *zeigen*, daß alle primitiven nicht auflösbaren Permutationsgruppen vom Grad $d \leqslant 15$ als Galoisgruppen über Q(t) *realisiert werden können* (*siehe* [11] und [15]). Als Abschluß des ersten Abschnitts *werde ich* noch zwei Beispiele mit s = 4 *aufführen*:...
>
> (A-11)

As already mentioned, *ich* as a way of the author's self-reference supports deictic interpretation of other potentially deictic elements. *Wir* would then also be interpreted as *ich* + *du*, the reader. In most cases this is not a desirable interpretation since no real actions are carried out jointly by the author and an individual reader. In

example 4.17 data, the author refers to himself using *ich* and avoids any reference to the audience, except via PF for predicates such as *zeigen* ('to show') or *geben* ('to give') and except in the standard Singular expression *siehe* ('see'). Reference to other authors is made directly by proper names or indirectly by impersonal passives with a locative phrase. The general statements are made by means of *man*-clauses and impersonal (passive and infinitive) constructions.

Wir can be used also as a direct self-reference. This is the case when a paper is written by two or more authors, which necessarily rules out the use of *ich*. It seems that in one coherent piece of written discourse, i.e. in one paper, *wir* is rarely used simultaneously for direct and indirect reference. If *wir* is used for direct self-reference, *man* is a preferred form of addressing the audience.

In general, there is no need to relate the statements of mathematical facts to any persons, there is even no obvious way of relating them to humans. Bringing a general truth into a perspective of a single person necessarily limits the scope of its validity.

While in the written discourse self-reference with the pronoun *ich* is still relatively rare (although this convention may change), *ich* is used quite naturally in the spoken discourse. In the case of a spoken communication, the presence of the speaker and the audience makes a direct reference the obvious choice, at least in some parts of discourse (e.g. when the speaker refers to operations he himself performs on the blackboard etc.).

Examples illustrating the use and the implications of *ich* in the spoken mathematical discourse are given in the next subsection, where the direct reference to the audience is considered.

4.4.2 Direct Reference to the Audience

Once the speaker introduces a direct way of self-reference, the reference to the audience may also be made more explicit, i.e. the audience may be addressed directly by forms of the 2nd Person or by the polite form *Sie*. In the spoken discourse we found only the *Sie*-forms of addressing the audience. The more informal *Ihr* would violate the social convention. The singular form *du* was not possible as a form of addressing the collective audience because of its individualizing effect.

The audience may be addressed also by an inclusive *wir*, and to find out whether it represents direct or indirect reference we have to consider the meaning of the predicate. In the case of directly referential use of *wir* (= *ich* + *Sie*) the audience (i.e. the extension of *Sie*) must be a participant in the event described by the predicate (i.e. must belong to the extension of that predicate). Other cases, i.e. the indirectly referential use of *wir* , were discussed in Subsection 4.4.1. Here, we concentrate on the question of the distinction between directly and indirectly referential use of *wir* based on the semantic properties of the lexical predicate. The following passage illustrates the use of some directly referential expressions in the spoken mathematical discourse:

Example 4.18

> ...wenn jetzt dieses kleiner gleich lambda ist dann *setzen wir* das einfach *ein*/ also das ist irgendwie ganz einfach/also wenn dies jetzt ... dann *können Sie's einsetzen*/... damit *sind wir ein schritt weiter*/also *wir brauchen* jetzt die gruppe von kontraktionen *zu betrachten*/das problem das jetzt zunächstmal noch besteht ist/es könnte hier noch m stehen/.../und darüber *wissen wir* im moment *nichts*/aber jeweils dieses ... *kriegen wir weg*/was *wir uns* also noch *merken müssen* ist wenn *wir* statt einer kontraktionshalbgruppe *haben* eine allgemeine .../dann *bringen wir* das omega t einfach *weg* .../und was übrig bleibt ist ... sind beschränkte halbgruppen .../und dieses problem das *werden wir* auch *aus der welt schaffen* aber nicht sofort...

and further:

Example 4.19

> ...und zwar das was *ich hier jetzt präsentiere* ist natürlich nicht der anfang der geschichte sondern das ende/nicht? /zunächstmal wurde die sache natürlich für Hilbert-räume gemacht/und dann ging es natürlich darum wie findet man eine richtige verallgemeinerung für Banach-räume und bei den bedingungen die *ich* ja zunächstmal *ausschreibe denken Sie sich* vielleicht zunächtstmal an den Hilbert-raum .../*ich formuliere* es aber gleich für Banach-räume/und zwar geht es also jetzt .../das ist jetzt nämlich sehr abstrakt zunächstmal/also *ich bitte sie* das einfach so *zu schlucken* zunächstmal ...
>
> (B-2)

In Section 4.2 we have said that in the restricted context of scientific communication certain semantic classes of predicates are associated with specific participants in the situation of communication. Thus predicates used to describe the activities of presenting knowledge (e.g. *angeben* ('to give') or *zeigen* ('to show') have the speaker as a prototypical referent of the 1st participant slot in their PFs, and the immediate or potential audience as a referent of the 3rd participant slot. On the other hand, predicates used to describe specific mathematical operations to be carried out on mathematical objects are not associated with any referential constraints. The examples of this class of predicates in 4.18 and 4.19 are: *einsetzen* ('to substitute'), *wegbringen* ('to remove'/'to eliminate'). Other examples of this type are verbs such as *addieren* ('to add'), *dividieren* ('to divide') as well as some predicates that have been used in mathematics in a restricted 'metaphorical' meaning, as e.g. *lösen* ('to solve'). For these verbs the prototypical semantic specification on the 1st participant slot does not change in the restricted context, i.e. no additional, role-related features are supplemented. Since predicates in this class are referentially neutral, i.e. they are used to describe certain mathematical operations in general, their interpretation is very sensitive to the choice of the lexical items in the 1st participant slot.

If the neutral, general interpretation of these predicates is to be preserved, i.e. if the focus is on the properties of mathematical objects or relations, then indefinite expressions are used or the 1st argument slot is left empty. If predicates from this class are associated with pronouns *ich*, *wir* (in a paper written by two authors), *du* or *Sie*, the expression is interpreted unambiguously as direct reference. Thus, the only pronouns that are referentially ambiguous (direct versus indirect or general reading) are instances of *wir* in spoken or written discourse by a single author.

Here we comment on one particular case of directly referential use of *wir*, and we repeat as (78) a clause quoted in example 4.18:

(78) ... damit sind *wir* ein schritt weiter
'... with that we are a step further on .

The *wir* in this example is directly referential, i.e. it is used to refer to the speaker and the audience (*ich* + *Sie* reference). Its

special feature is that it is bound by the semantics of the predicate in such a way that only the immediate participants in the communicative situation may be interpreted as its referents.

Similarly, in (79), where we repeat another passage from example 4.18:

(79) und dieses problem das *werden wir* auch aus der welt *schaffen* aber nicht sofort
'and this problem, we will get rid of that too, but not right away'

the use of Future Tense binds the referential scope of the pronoun. The deictic *wir* in (78) and (79) cannot be replaced by an indefinite *man*. The general *man* and *wir* are freely interchangable only if *wir* is used without any marking that would limit the scope of its possible reference.

Summarising these observations, we may formulate two constraints on the use and interpretation of referring expressions in a restricted context of scientific communication:

1. the personal pronoun *wir* cannot be interpreted as indirectly-referential in contexts bound by specific temporal (i.e. Past, Future and non-general Present Tense) or local markers;

2. the indefinite personal pronoun *man* cannot be used as general in contexts bound by markers related to the immediate context of communication.

We pointed out that the Singular form of the 2nd Person, *du*, cannot be used to address the real audience in the case of a spoken mathematical discourse. This constraint is conditioned by two factors. *Du* would be considered as too informal (as it is also the case for *Ihr*) and it would contradict the obvious collectiveness of the audience. However, these two factors affect only the communication with immediately present audience. They can be ignored in the written scientific discourse, primarily because reading is usually an individual activity. Thus the author may address an individual reader and the Singular 2nd Person forms are allowed. It is a well established convention in written scientific discourse to use 2nd Person Singular imperative forms such as *vergleiche* ('compare') or *siehe* ('see') and they are not considered as

indicating informal style. It is, however, not common to find other than conventional instances of the Singular 2nd Person forms. If they occur, they mark the style of the particular author as informal. We illustrate this with another passage from Landau [1930]. In the introduction to his handbook of analysis (*Vorwort für den Lernenden*) he wrote:

Example 4.20

1. Bitte lies nicht das nachstehende Vorwort für den Kenner! ...
3. Bitte vergiß alles, was Du auf der Schule gelernt hast; denn Du hast es nicht gelernt.

(A-5)

Landau must have been aware that this was not a conventional way of addressing the reader. The introduction ends:

Example 4.21

5. Entschuldige, daß ich Dich duze; dies geschieht nicht nur, weil man den Leser mit "lies" und "siehe" anzureden pflegt, sondern weil dies Buch zum Teil in usum delphinarum geschrieben ist ...

(A-5)

However, in the following introduction for a specialist (*Vorwort für den Kenner*) the style is again more formal and no *du* forms are used, since they would violate social convention. This introduction ends:

Example 4.22

Wenn aber gar *dem einen oder anderen Kollegen* der anderen Richtung die Sache so leicht erscheint, daß *er* sie in *seinen* Aufängervorlesungen (...) bringt, würde *ich* ein Ziel erreicht haben, auf das *ich* in größerem Umfange nicht zu hoffen wage.

(A-5)

These forms of addressing the audience in a more or less formal but direct way are limited to the introduction and do not occur in the scientific discourse itself. This is why we left them out in the discussion and considered them only as a marginal phenomenon of direct reference.

In the last section of this chapter we present the results of a pilot count, carried out on a small sample of the data. This analysis shows that the common belief in the apparently impersonal character of mathematical discourse requires revision.

4.6 Analysis of Text Samples

4.6.1 Methods

A pilot count was carried out on the text samples (A-9 and B-6) from the two text corpuses described in Subsection 4.1.2. The samples consisted of 146 and 195 clauses. Fourteen multilevel criteria were used to describe the internal clause structure, taking into account syntactic and semantic aspects. No attempt was made to present a more exhaustive analysis of the data available, although we intend to extend this line of research in the future. The pilot study was meant as a check of the proportion of *personal* and *non-personal* clauses in mathematical discourse. We chose the criteria of description to indicate whether anything in the clause points to the speaker, i.e. can be considered as the speaker's reference to himself. Clauses containing one or more 'self-referential' elements are treated as *personal*, i.e. allowing for a personal interpretation.

Below we list the criteria and their levels used for description of the internal clause structure. The first three criteria were necessary merely for identification of clauses. Criteria 4 and 5 describe the level of structural complexity of sentences, i.e. are not directly relevant for the interpretation of reference.

1. Case identification number

2. Text number

3. Sentence number

4. Number of clauses in a sentence

5. Level of the clause subordination

   0 - for a simple clause or the main clause of a complex sentence; 1 - for a clause subordinated to the main clause; 2 - for a clause subordinated to a subordinate clause of level one, etc.

6. Semantic verb type (according to the classification presented in Subsection 4.2.1):
   1) prototypical action verb
   2) cognitive action verb

3) event verb
4) middle verb
5) relational-equative verb
6) relational-attributive verb
7) relational-locative verb
8) others

7. Verb form
1) simple active
2) modalised active
3) pseudo-reflexive
4) modalised pseudo-reflexive
5) *werden*-passive
6) *sein*-passive
7) infinitive construction
8) *zu* + infinitive construction
9) modalised passive

8. Mood:
1) indicative
2) full imperative
3) periphrastic imperative
4) voluntative *Konjunktiv I*
5) *Konjunktiv I* or *II*
6) interrogative
7) periphrastic interrogative

9. Time reference:
1) present (i.e. *Präsens*)
2) past (i.e. *Präteritum*, *Perfekt*, *Plusquamperfekt*)
3) future (i.e. *Futur I* and *II*)
4) not applicable (e.g. in the case of clauses with non-indicative mood)

10. Number of explicit arguments as compared with the number of PF arguments:
1) equal to the number of PF arguments
2) less

11. Semantic characteristics of the lexical subject NP:
    1) + Human (lexically fully specified)
    2) Human-like (e.g. personification of computers etc.)
    3) + Inanimate
    4) *man* (+ Human but not lexical)
    5) dummy subject *es*
    6) event (i.e. a complex phrase or clause referring to an 'event')
    7) Ø (no explicit subject)

12. Prototypical semantics of the 1st participant:
    1) + AGENT (i.e. prototypically human)
    2) OTHER (i.e. no restrictions)
    3) + TARGET (i.e. prototypically inanimate)
    4) not applicable (i.e. PF{Ø})

13. Clause constituent corresponding to the 1st participant:
    1) subject
    2) another complement (i.e. 1st participant demoted)
    3) non-argument (i.e. 1st participant presented as e.g. free Dative in pseudo-reflexive construction or corresponding to the possessive pronoun modifying the subject in infinitive constructions)
    4) Ø (omission of the 1st participant)
    5) not applicable

14. Evolving subject perspective (i.e. subject of the current clause is referentially identical with on of the following):
    1) last subject
    2) one of the previous subjects
    3) previous argument
    4) element of the previous discourse, however, without argument status
    5) something newly introduced
    6) something inferrable
    7) not applicable (e.g. in subjectless constructions)
    8) dummy *es*
    9) previous statement as a whole

15. Means of the speaker's self-reference:
    1) *ich*
    2) generalised *wir* excluding the audience
    3) generalised *wir* including the audience
       (This distinction is due to the predicate semantics and, consequently, to different links betwen predicate arguments and discourse participants, as described in Section 4.2.)
    4) indirect self-reference via PF
    5) reference to the context of writing/speaking
    6) use of evaluative modifiers
    7) other means of self-reference (e.g. Tense, Mood, etc.)
    8) Ø

16. Means of the speaker's reference to the audience:
    1) full imperative
    2) generalised inclusive *wir*
    3) periphrastic and other forms of imperative
    4) indirect reference via PF
    5) question
    6) reference to the context of reading/listening
    7) other means of reference to the audience
    8) Ø

17. Other than personal means of deixis:
    1) spatio-temporal deixis
    2) text-deixis
    3) other deictic elements
    4) Ø

Underlined are those levels which indicate the speaker's presence in direct or indirect way. This may be the speaker's explicit reference to himself, some form of his reference to the audience, or reference to the context of communication.

The following analysis was performed using the SPSSx computer package (cf. *SPSSx User's Guide* [1983]).

Personal clauses, i.e. those containing at least one of the underlined characteristics, were counted. At the following stage we analysed certain dependencies between the semantic and referential characteristics of clauses. In particular we looked at the *semantic*

verb type and the *personal* or *non-personal* status of a clause to see whether there is a systematic relationship between these two features. The results of this count are presented in the following section.

To give an indication as to whether the sample size of 195 clauses is large enough, we give the following calculation.

> Let p be the true (population) proportion of personal clauses;
> Let P be the discovered relative frequency of personal clauses.

Then, under some assumptions of independence, the 95% confidence limits for the population p are:

$$P \pm 1.96 \sqrt{p(1-p)/N} .$$

Replacing N by 195 we have

$$P \pm 1.96 \sqrt{p(1-p)/195} .$$

The 95% confidence interval will become <u>at least 95%</u> confidence interval if we replace p by ½.

$$= P \pm 1.96/\sqrt{780}$$

$$= P \pm 0.070 .$$

This means that if the appropriate assumptions hold, the proportion of personal and non-personal clauses in German mathematical discourse, which is estimated on the basis of 195 cases, has a 95% confidence interval not longer than 0.14. This accuracy is absolutely sufficient for our purposes. However, we should note that the assumptions underlying the above calculation (i.e. the assumption that each clause, independently of all others, had the probability p of being personal) are evidently not fulfilled. This is due to the fact that individual styles of authors and text types allow for a different degree of usage of personal and non-personal clauses. Let the above calculation be just an informal justification of the limited sample size.

4.6.2 Results

The count of the frequency of personal clauses in the two samples gave the following results. In the data sample from written discourse 107 clauses out of 195 were classified as *personal* (55%) and 88 as *non-personal* (45%). In the data sample from spoken discourse 121 clauses out of 146 were classified as *personal* (83%) and 25 (17%) as *non-personal*.

The number of clauses with verbs associated prototypically with the human 1st participant was 28 (14%) for the written and 16 (11%) for the spoken discourse. This clearly shows that also clauses with predicates other than those denoting prototypical or cognitive actions, were given *personal* interpretation.

In the written discourse, among clauses with verbs associated with prototypically human 1st participants 20 (71%) had ~~the~~ the 1st argument of the predicate overtly expressed. In the spoken discourse this figure was 11 what amounted to 69% of the predicates associated with prototypically human 1st participants. This shows that the remaining number of clauses with personal predicates (ca. $^{3}/_{10}$) involved indirect reference to the agent-like participant.

We did not refer here to all of the criteria listed in Subsection 4.6.1 since not all of them were employed in the quantitative check. The computer count was carried out on a sample of size 195. We were interested in options available for a speaker rather than in the estimates of frequencies of their usage.

We must note here that frequencies of usage of particular forms change in time, that is depend on rhetorical fashions of a given period. They obviously also depend on individual tastes. Further computer analyses can give more interesting results for phenomena other than the ways of the speaker's reference to the participants in the communication. For example, the evolving subject perspective or the dependency between the syntactic structure of a clause, the word order and the functional sentence perspective could be further analysed in terms of the criteria given in Subsection 4.6.1. These analyses obviously require larger data samples and, more importantly, a randomised approach to the selection of texts and analysed clauses. They were, however, beyond the scope of the research presented in this thesis.

CHAPTER 5

RESULTS AND CONCLUSIONS

5.1 Summary of Results

5.1.1 Systems of Reference in Spoken and Written Mathematical Discourse

In the preceding chapters we have

1. described syntactic and semantic properties of German impersonal constructions (Chapter 1);

2. set up a pragmatic background for their analysis as means of indirect reference in scientific discourse (Chapter 2);

3. developed a model to describe non-isomorphic mapping between syntactic and semantic representations of German impersonal constructions (Chapter 3);

4. presented the analysis of indirectly referential expressions in German mathematical discourse (Chapter 4).

In this chapter, we first summarise the results of the analysis presented in Chapter 4. We also point out differences between the reference systems used in spoken and written mathematical discourse and indicate some changes in the reference systems used in mathematical texts at different times (Section 5.1). Then, in Section 5.2, the final conclusions are stated and some lines of further research suggested. In particular, other linguistic phenomena are indicated which could be analysed in terms of the criteria proposed in this thesis.

Spoken mathematical discourse is in many respects very similar to the written discourse. In particular, statements of mathematical facts (i.e. theorems and theorem-like statements) commonly have the same form in written and spoken discourse. Most differences between the two sorts of discourse relate to the speaker's/author's presentation of self and to his reference to other participants in the communication.

In Section 4.4 we presented arguments in support of the thesis that in the restricted context of mathematical discourse the means of indirect reference constitute a complete system of reference. Here we shall further discuss this point and indicate differences between the system of reference in spoken and written mathematical discourse.

By saying that means of indirect reference constitute a complete system we mean that within an indirectly-referential framework it is possible

to point to each of the discourse participants in a distinctive way. This, in turn, means that a system of indirect reference can (in an appropriate context) effectively replace a direct system of reference and is able to take over all its functions. It provides a distinctive means of self-reference, means of referring to the immediate audience including the speaker, means of referring to the audience only and, finally, means of referring to the shared knowledge on the subject, personified by the 'encyclopaedic' reader or general audience.

There is, however, no single system of indirect reference valid for all instances of mathematical discourse. The fact that various initial choices (i.e. choices of means of the author's self-reference) are possible and that, consequently, various indirectly-referential frameworks may be set up, was discussed in detail in Section 4.4. There, we also indicated that indirect reference works differently in spoken and written discourse. Here, we point out and discuss two aspects of that difference. The first one concerns preferred interpretations of reference, the second relates to the scope of validity of the established systems of reference.

Spoken discourse, i.e. a mathematical lecture, necessarily involves some form of deixis. The immediate presence of the speaker and the audience, the fact that they share the situational context (i.e. time and place of communication) justify the use of deictic elements as the most economical way of referring.

Therefore, if the pronoun *wir* is used without any preceding discourse, for instance in a passage opening a lecture, it will be interpreted as referring directly to the speaker and the audience together. This is a preferred interpretation even if the lexical meaning of the predicate could suggest pragmatic links with a different discourse participant. Thus, for instance, in Example 5.1, the predicate *definieren* ('to define') is prototypically linked with the speaker as referent of the 1st argument position of the PF. Nevertheless, when there is no previous discourse which would introduce indirect self-reference of the author, *wir* is more likely to be interpreted as direct reference to the speaker and the audience together. The joint interpretation would probably be preferred for predicates prototypically linked with the audience, such as e.g. *lernen* ('to learn'). (This possibility was suggested to me by one of the lecturers from the Department of Mathematics in Kiel. There

are, however, no examples of this sort in our corpus.) Thus, *wir* in the invented example (1):

(1) letztes mal *haben wir gelernt* was man unter einer transzendenten erweiterung versteht
'last time we have learned what one understands by a transcendental extension'

would probably be interpreted as speaker's *polite* reference to the audience. This effect of politeness is achieved by including oneself among those who are referents of the 1st argument position of *lernen*.

In general, in spoken mathematical discourse the deictic, directly-referential reading of *wir* is favoured. Below are three examples of the lecture opening passages illustrating the use of *wir:*

Example 5.1

wir hatten in der letzten sitzung *definiert* was man unter einer algebraischen erweiterung versteht und unter einer transzendenten erweiterung/und dann *haben wir* den satz drei fünf-und-zwanzig...

(B-3)

Example 5.2

... und wenn *wir* heute den satz ... *beweisen wollen*.../ja letztes mal *haben wir uns* so mit trennungseigenschaften *beschäftigt/haben* also konvexe mengen die leeren durchschnitt hatten durch hyperebenen *getrennt*/heute *wollen wir uns* erstmal auch ein bißchen mit hyperebenen *beschäftigen* und dann *werden wir... betrachten...*

(B-5)

Example 5.3

... ja da *wollten wir* ja jetzt *uns* dieser gausschen periodentheorie da *zuwenden*/und diese ... besagt *uns* folgendes/ *wir haben* eine ungerade primzahl d hoch p/ungerade/und *wir betrachten* daß p der gleichteilungspolynom ist/ich nenn das wie immer pi t von p/.../und *wir wollen* das ding algebraisch *auflösen*...

(B-2)

In the examples 5.1-5.3 *wir* is used with predicates prototypically linked with the speaker (e.g. *definieren* ('to define'), *beweisen* ('to prove')) as well as with predicates with no prototypical links (e.g. *sich beschäftigen* ('to be occupied'), *betrachten* ('to consider')). In the lecture opening passages, expressions with both verb types are interpreted as direct reference (*ich* + *Sie* reading). This interpretation cannot be affected by the use of tenses other than *Präsens* (*Plusquamperfekt* in example 5.1, *Perfekt* and *Futur I* in example 5.2, *Präteritum* in example 5.3) since these departures from the general Present Tense support the deictic use of *wir*.

In written discourse, on the other hand, it is conventional to employ indirect reference. This does not rule out directly referential interpretation if a paper is written by two or more authors as is the case in example 5.4:

Example 5.4, paper by two authors

1. Einleitung

Die Frage, ob jede geschlossene Mannigfaltigkeit eine nicht-triviale Operation einer kompakten Liegruppe G auf sich zuläßt, ist von verschiedenen Autoren negativ beantwortet worden... . *Wir zeigen* **hier** unter anderem daß... .

(A-7)

Except for articles written by more than one author, *wir* in the passage opening a mathematical paper (i.e. being the first referring expression in the discourse) may be interpreted either as author's indirect self-reference or as his reference to himself and to the possible readers, i.e audience remote in time and space. Which interpretation is preferred depends on the lexical predicate and its link with discourse roles, and on the deictic elements used to support reference (indicated by bold print). Example 5.5 illustrates the indirctly self-referential use of *wir* since the 1st argument position of *geben* ('to give') is in this restricted context linked with the role of the speaker:

Example 5.5

1. Einleitung

Es seien X eine Zufallsgröße und f(t) ihre charakteristische Funktion. **In dieser Note** *geben wir* eine Charakterisierung der Nullstellenmenge von f(t) in den folgenden drei Fällen: ... .

(A-9)

In example 5.6 *wir* is also used for self-reference. This interpretation is supported by the use of the Past Tense and by text-deictic phrases, (*in ... der vorliegenden Arbeit* and *im folgenden*).

Example 5.6.

Einleitung

In Teil I der vorliegenden Arbeit *betrachteten wir* eine Verallgemeinerung des Schmidt-Bachmannschen Axiomensystems der absoluten Geometrie, der auch die minkowskische Geometrie genügt (das Axiomensystem A). **Im folgenden** *wird* der über das Schmidt-Bachmannsche Axiomensystem hinausreichende Teil des Axiomensystems A (das Axiomensystem A') *untersucht*.

(A-12)

Note that in the above example 5.6 self-reference in the discourse-opening clause is achieved by the generalised *wir* and in the clause immediately following impersonal passive is used in the same function. Both instances of indirect self-reference are supported by coherent deictic elements pointing to the author as intended referent.

The use of *wir* for referring to the author and those who want to follow his argument is illustrated in example 5.7.

Example 5.7

In seinem Tagebuch ... notiert C.F. Gauss am 9. Oktober 1796 den Satz, dass für eine ungerade Primzahl p jede nicht triviale ganzzahlige Linearkombination der primitiven p-ten Einheitswurzeln von Null verschieden ist. Dies ist offenbar gleichwertig mit ... . *Bezeichnen wir* allgemein mit W(f(t)) den von den Nullstellen eines Polynoms f(t) erzeugten Q-Teilraum von C, so *können wir* den Satz von Gauss in der Form aussprechen: ... .

(A-3)

This interpretation is achieved by the conditional form 'if-then', not bound by any deictic elements. Predicates *bezeichnen* ('to denote') and *aussprechen* ('to express') are relatively free, i.e. do not necessarily require a constant link with the speaker as a referent of their 1st argument positions.

Thus, for spoken mathematical discourse, the deictic, direct reference is a favoured (default) option for interpretation. In written

discourse, on the other hand, where the impersonal rhetoric of science is the usual convention, indirect reference is preferred. These two discourse types are governed by rules specific for each of them separately, and even one and the same person changes his/her system of referring according to the mode of presentation (spoken versus written). Our corpus contains two examples of written and spoken discourse from the same speaker/author (for two different individuals). These are the pairs A-3, B-2 and A-12, B-6. In both cases *ich* self-reference is used only in the spoken discourse and *wir* as indirect self-reference (i.e. excluding the audience) is used only in written discourse, supported by the text-deixis. We may conclude that spoken and written mathematical discourse are pragmatically distinct and that this difference results in the choice of one or other distinctive system of reference.

The second interesting difference between the systems of reference in spoken and written mathematical discourse is that of the scope of validity of established frameworks of referring.

In a mathematical paper, i.e. in written discourse, systems of reference work *globally*. Once a framework is set up, it remains valid ~~for the~~ for the whole paper. If, for example, the generalised *wir* is chosen for self-reference, we do not expect to encounter, and in fact do not encounter, any instances of *ich* used in the same function. Written discourse is thus referentially *coherent*, which seems to be an obvious consequence of a higher level of impersonality, a sophisticated system of indirect reference and of the nature of writing in general, with time to change syntax and polish up the language.

In spoken discourse, systems of reference work *locally*, that is more than one framework of referrring may be used during the same lecture. These local frameworks vary mainly in the speaker's choice of term for self-reference (*ich-wir-man*) and in the speaker's choice of term for reference to the audience (*Sie-wir-man*). Because in spoken discourse deixis is legitimate, reference interpretation within the changing framework is supported and facilitated by various deictic elements. Thus, in spoken discourse reference systems are only *locally coherent*, i.e. apply to parts of discourse, not to discourse as a whole.

We can find an analogy for local systems of reference in written discourse, namely in monographs, where the framework of reference may be different in the preface (more personal, i.e. direct) and in the text

itself (indirect). This phenomenon was illustrated with examples in Section 4.5 (cf. examples 4.22 - 4.24). A different system of reference may also be found in the 'summary' section of some scientific papers. The 'summary', contrary to the 'preface', usually represents the most indirect and impersonal type of reference.

The following diagrams illustrate the hierarchical nature of the system of indirect reference and summarise the referring techniques used in written and spoken German mathematical discourse.

Note, that there is a difference between written and spoken discourse in the possible ways of referring to the audience. In the written discourse we distinguish between reference to an individual reader and reference to the general audience. No means of joint reference to the speaker and the reader were found in our corpus. In the spoken discourse, on the other hand, we distinguish between the speaker's reference to the audience and himself together, and his reference to the audience only. Note also, that no means of direct reference to the general audience were found in our data from written discourse.

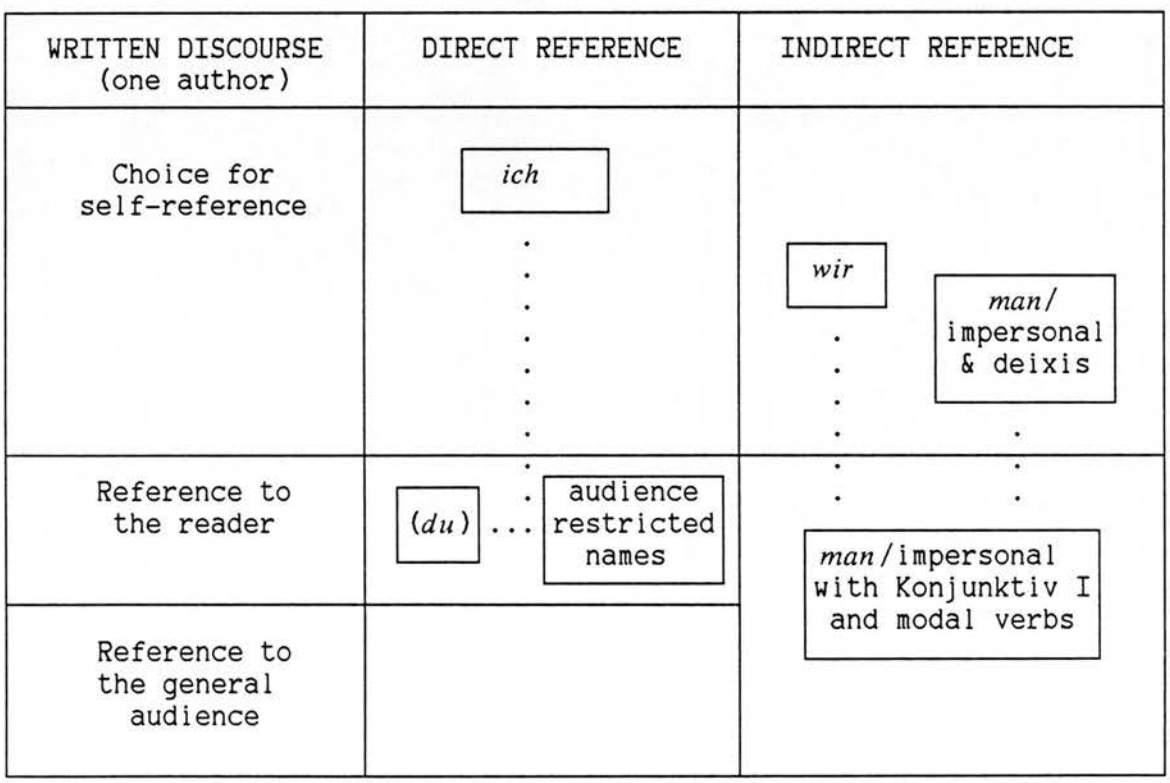

Figure 4. System of referring in written discourse, one author

WRITTEN DISCOURSE (two authors)	DIRECT REFERENCE	INDIRECT REFERENCE
Choice for self-reference	*wir*	*man*/ impersonal & deixis
Reference to the reader	audience restricted names	*man*/impersonal with Konjunktiv I and modal verbs
Reference to the general audience		

Figure 5. System of referring in written discourse, two or more authors

SPOKEN DISCOURSE	DIRECT REFERENCE	INDIRECT REFERENCE
Choice for self-reference	*ich*	*wir*; *) *man*/ impersonal & deixis
Reference to the audience and the speaker	*wir*	*wir/man*; impersonal
Reference to the audience only	*Sie*	*man*/impersonal with Konjunktiv I and modal verbs

*) possible only as a local framework

Figure 6. System of referring in spoken discourse

5.1.2 Development of Referring Strategies

A comprehensive analysis of the development of referring strategies in mathematical discourse is beyond the scope of this thesis. It would require investigation of a large body of mathematical texts from different epochs and by different authors. Thus, in the remarks presented in this subsection we do not attempt to give a general picture of the changing rhetoric of mathematics. We merely indicate to what extent results from the analysis of contemporary mathematical discourse, discussed in this thesis, are valid for older texts. To achieve this aim, we looked at some original German mathematical texts from the 19th century and at 19th and early 20th century translations of other texts.

As was indicated in Subsection 2.2.4, mathematics has a unique status among the arts and sciences. The special nature of mathematics is closely related to the special character of mathematical creation and discovery. Henri Poincaré (1854-1912), French mathematician and philosopher, described this phenomenon as follows:

> "The genesis of mathematical discovery is a problem which must inspire the psychologist with the keenest interest. For this is the process in which the human mind seems to borrow least from the exterior world, in which it acts, or appears to act, only by itself and on itself, so that by studying the process of geometric thought we may hope to arrive at what is most essential in the human mind."
>
> Poincaré [1952] p.46

We may assume therefore, that the general nature of mathematical discovery is independent of time and culture, and as such that it has not changed. On the other hand, the creative character of mathematical activity necessarily brings the individuality of the author into consideration. Yet another factor which must be taken into account is the rhetoric of mathematics. Rhetoric in general is, as Kaplan [1972] put it, "not universal... but varies from culture to culture and even from time to time within a given culture. It is affected by canons of taste within a given culture at a given time" (p.7).

It seems that the rhetoric of science generally develops towards a more *personal* presentation of the research performed. The impersonal rhetoric, however, was and still is a neutral convention in many works and for many scientists. In mathematics, the impersonal rhetoric is supported by the a-personal nature of mathematical statements and by the growing level of formalism in their expression.

Taking into account the above mentioned factors, we might expect that mathematical texts written in the 19th century will not differ considerably from modern mathematical discourse as far as the expression of mathematical statements is concerned (apart from differences due to the general development of the German language and to the changing formalism). Also, as we find individual differences with respect to the presentation of self in modern mathematical discourse, we may expect to see individual differences in referring strategies in older texts. Interesting, from the point of view of the research presented here, is the question, whether certain principles of indirect reference applied in texts written one or two centuries ago.

Our analysis, necessarily limited, concentrated on the following texts:

Euclid (365- ca. 300 b.c.) *Die Elemente* ('Elements'), translation from Greek, published in Leipzig 1933;

L. Euler (1707-1783) *Mechanik* ('Mechanics') translation from Latin, published in Greifswald 1848;

C.F. Gauss (1777-1855) *Allgemeine Flächentheorie* ('General theory of planes'), written in 1827, translation from Latin, published in Leipzig 1921 (5th edition);

C.F. Gauss *Disquisitiones Arithmeticae*, translation from Latin, published in 1889;

C.F. Gauss *Zur Theorie der complexen Zahlen* ('On the theory of complex numbers'), published in *Werke*, Vol. 2, (2nd edition), Göttingen, 1876;

C.G.J. Jacobi (1804-1851) *Zur Theorie der elliptischen Functionen* ('On the theory of elliptical functions'), published in Berlin 1881;

F.G. Frobenius (1849-1917) *Zur Theorie der elliptischen Functionen* ('On the theory of elliptical functions'), first published in *Journal für die reine und angewandte Mathematik* in 1877;

The most striking difference between the above listed texts and texts discussed in Chapter 4, is a higher level of syntactic complexity of impersonal constructions used for indirect reference. Since impersonal rhetoric was clearly a prevalent convention in 19th century mathematics, the resulting impression is one of a highly impersonal style of narration. We find this even in those parts of a text which are usually most personal, e.g. in a preface written by the editor. We may illustrate this phenomenon with a final passage from the editor's

preface to the 1889 edition of Gauss's *Disquisitiones*:

Example 5.8

> Da nun die 'Disquisitiones arithmeticae' ein durch seine Form hervorragendes klassisches Werk sind, *so kann das Studium* derselben im Originaltext *nicht dringend genug empfohlen werden*. Wem es aber zunächst nur darum zu thun ist, mit dem Inhalte selbst bekannt zu werden, der wird es jedenfalls dankbar annehmen, *wenn es ihm* durch Hinwegräumung äusserer Schwierigkeiten *ermöglicht wird*, seine ganze Aufmerksamkeit auf die Sache zu richten. Daher *darf man sich immerhin der Hoffnung hingeben*, dass die vorliegende deutsche Ausgabe vielen Lesern sehr willkommen sein wird .

The sophisticated form of indirect self-reference, illustrated with the last phrase, *darf man sich der Hoffnung hingeben*, cannot be considered as a generally accepted convention in older texts. The editor's preface to the 1848 German edition of Euler's *Mechanik* shows a different referential framework with *ich* as initial choice. Below, we quote the opening and the closing sentences:

Example 5.9

> Das vorliegende Werk *hatte ich*, um es gründlich kennen zu lernen, dermassen *studiert*, dass *ich* es in's Deutsche *übertrug* und alle Stellen, welche *mir* von selbst nicht klar waren, durch Worte und Calcul *zu erläutern suchte*.
>
> ...
>
> Dieses Vorwort *hielt ich* für nothwendig, um zu bewirken, dass das Werk aus dem richtigen Gesichtspunkte betrachtet werde und *spreche schliesslich* den Wunsch *aus*, dass dieser I. Theil eine günstige Aufnahme finden möge .

Also in the following translation of the introduction written by Euler, direct self-reference with *ich* (corresponding to the 1st Person Singular form of the verb in the Latin original) is used. However, in the mathematical text itself, only indirect means of self-reference are used. *Ich* appears only in comments added by the editor and clearly distinguished from Euler's original. In this case, two different systems of reference run parallel (but separate) in one piece of discourse.

An indirect system of reference is also used by Frobenius (*wir* - *man* - impersonal passive and infinitive constructions) and in all three translations of Gauss. As was illustrated in Subsection 2.3.2, Gauss used to write in an 'impersonal' manner even in his private mathematical diary. In his strictly mathematical writing, he follows impersonal rhetoric and uses a highly sophisticated system of indirect reference which we illustrate with the fragment below.

Example 5.10

> *Wir haben* allgemein die identische Gleichung... . Aus dieser neuen Auflösung *kann man* auf gleiche Weise eine dritte *ableiten* u.s.w. *Man überzeugt sich leicht*, dass wenn die erste Auflösung in reellen Zahlen ist, auch die dritte eine solche sein wird. *Es ist noch zu bemerken*, dass wenn a, b, c keinen Factor gemein haben, dasselbe auch von a', b', c' gelten wird... .
>
> from Gauss's *Zur Theorie der complexen Zahlen*

Among the referring expressions in 5.10, *wir* points to the speaker and audience together; the first *man*, and the *es ist zu bemerken* construction point to the audience.

The interpretation of indirect self-reference is supported by deictic and text-deictic elements (in bold print), as is illustrated below:

Example 5.11

> Da **im Folgenden sehr** häufig solche Potenzen der Wurzel r *zu betrachten sind*, deren Exponenten wiederum Potenzen sind, derartige Ausdrücke aber im Druck nicht ohne Schwierigkeit wiedergegeben werden können, so *werden wir uns* zur Erleichterung des Druckes **im Nachstehenden** der folgenden Abkürzung *bedienen*.
>
> from Gauss's *Disquisitiones*

It is an interesting difference, if compared with modern mathematical discourse, that the deictic function of the system of grammatical tenses is exploited to a much larger extent. Modern discourse prefers the general Present Tense even for description of future events. An example of the use of the Future Tense (*Futur I*) is given in 5.11 above, *so werden wir uns ... der folgenden Abkürzung bedienen*. Other examples are given below:

Example 5.12

> Das Ziel **der nachfolgenden Untersuchungen**, *welches kurz anzugeben nicht unnützlich sein wird...*
>
> from Gauss's *Disquisitiones*

Exaple 5.13

> In Flüssigkeiten sind nämlich, wie *wir* **später** *sehen werden*, wo von der Bewegung der Körper in ihnen *die Rede sein wird*, die bei gleichen Geschwindigkeiten hervorgebrachten Widerstände den Dichtigkeiten der erstern proportional .
>
> from Euler's *Mechanik*

Note that in the examples above the Future Tense is used to refer to the following parts of the paper itself, i.e. its function is also text-deictic. In modern texts Present Tense would be used.

The individual nature of the author's initial choice of terms for self-reference is confirmed by the fact that direct self-reference may still be used although it apparently violates rhetorical principles. We find examples of direct self-reference in the 1881 edition of Jacobi's *Gesammelte Werke*. Here we quote the passage opening the chapter on the theory of elliptical functions:

Example 5.14

> Unter den Formeln, durch welche man die vielen von *mir* in den Fundam. nov. gegebenen Entwicklungen mit leichter Mühe noch vermehren kann, scheint *mir* die nachfolgende... einen eigentümlichen Character zu haben .
>
> from Jacobi's *Gesammelte Werke*

As we pointed out in Subsection 4.4.1, when *ich* is used as a means of self-reference, *wir* would also be interpreted as deictic which is not a desirable effect. Consequently, discourse examples with *ich* do not contain any instances of *wir*. The same was the case in the older texts we looked at.

In the 1933 translation of the Euclid's *Elements* we find practically no instances of the author's self-reference. The text, preceded by a set of definitions, axioms and postulates, consists of practical questions and their solutions. The indirect reference to the audience (via commands expressed with *man* + *Konjunktiv I*, *man* + modal verbs, or with infinitive constructions) may be considered as the only indication of

the existence of the narrator. This technique, however, cannot be directly compared with the 19th and 20th century mathematical discourse simply because Euclid's works (due to the fact that they were written over 2,000 years ago) could not be preserved as exactly as books or papers written in the last century. If anything was left out in the subsequent versions, these were most likely the extra mathematical elements, i.e. those which might have been marked as *personal*.

The limited scope of this analysis does not allow any generalisations. It seems, however, justified to conclude that, while rhetorical conventions and individual tastes vary, principles of semantic interpretation of language phenomena remain relatively stable.

5.1.3 Means of Impersonal Narration Unexploited in Mathematical Discourse

German offers a wide range of syntactic constructions which allow the language user to describe actions and events without any explicit reference to human participants, including himself. In Chapter 1 we presented German impersonal constructions and discussed their semantic interpretation. Since the rhetoric of mathematical discourse advises its disciples to write and talk in a possibly impersonal manner, we could expect that all linguistic means of impersonality available in the language, will be exploited. This, however, is not the case. Certain options are not used. In this subsection we look at some devices for achieving the impersonal style that are not exploited in mathematical discourse, namely some pseudo-reflexive constructions. We comment on the possible reasons for their non-occurrence.

Some transitive and intransitive German verbs, when used to refer to human activities, allow for impersonal, pseudo-reflexive constructions. Below, we discuss this type of impersonal constructions in more detail to illustrate how it is handled in terms of the PF model.

For transitive verbs, such as e.g. *lesen* ('to read'), the 2nd argument may be promoted to subject position. The 2nd argument promotion to the topical position, however, does not determine the clause structure in an unequivocal way. There are several options, passive being the most obvious choice. In this case, the predicate has passive morphology and the 1st argument may be, but does not have to be, left out. Other options are: infinitive constructions, i.e. *sich lassen* + infinitive of

the main verb and *sein* + *zu* + infinitive of the main verb. In both cases the 1st argument may, but does not have to be, omitted. Finally, the pseudo-reflexive construction may be used. Here the 1st argument **must** be left out and the verb is marked as reflexive. The reflexive pronoun is co-referential with the subject. The reflexive marking on the verb is necessary since the verb has not been properly detransitivised (i.e. has active morphology) and as such requires an object. The *semantic object*, i.e. the 2nd argument of the predicate, functions as syntactic subject. In the semantic representation, however, at PF level, it is still the 'object' of *lesen*. This discrepancy between syntax and semantics is indicated by the reflexive verb morphology, which signals the intended *middle* interpretation. Passive verb marking is just another way of signalling that the clause subject is not the 1st argument of the predicate. Here is an example of the pseudo-reflexive use of a transitive verb:

(2) a. Hans las dieses dicke Buch nur mühsam
'Hans read that thick book only with difficulty'
b. Dieses dicke Buch las sich (*von Hans) nur mühsam
'that thick book read (*by Hans) only with difficulty' .

The 1st argument demotion has different consequences for intransive verbs. There is no 2nd argument to be promoted and the subject position cannot be filled lexically. Since German requires an overt grammatical subject, *es* fills the subject position. The reflexive pronoun signals the *middle* reading. It may also be seen as co-referential with *es*, since both elements have a syntactic function only (i.e. both are semantically empty). This purely syntactic (formal) character of *es* is confirmed by the fact that in languages with subject-incorporation (e.g. in Polish) the function of *es* is taken over by verb morphology. In general, the semantic (and referential) interpretation of pseudo-reflexive constructions (for both transitive and intransitive verbs) must be arrived at by reference to the PFs of the relevant predicates. The examples below illustrate the pseudo-reflexive construction with an intransitive verb 'to sleep' in German and in Polish:

(3) *Es schläft sich* gut auf dem Lande
'One sleeps well in the country'
(4) Na wsi dobrze *się śpi*
'in the country, one sleeps well' .

(Note that Polish allows free Datives within the pseudo-reflexive construction, pointing to the 1st argument of the predicate:

(5) Na wsi dobrze **mi** *się śpi*
'in the country, I sleep well'.)

Both in German and in Polish, pseudo-reflexives are stylistically marked as colloquial. This may be one of the reasons for not using them in scientific discourse. However, there is yet another reason which, we believe, is the major factor in rejecting this type of construction. As was mentioned above, in contrast with other means of the 2nd argument promotion, pseudo-reflexive constructions do not allow for the demoted 1st argument to appear in the clause structure. This constraint suggests that the personal interpretation is 'blocked', i.e. that the PF specification of the prototypical 1st argument is not accessible. This becomes clear if we compare the two examples in (6):

(6) a. Die Tür öffnete sich
'the door opened'
b. Die Tür wurde geöffnet
'the door was opened' ,

where the first one concentrates on the event as such while the second implies some sort of external *agency*. The same argument could be used to explain why the *Zustandspassiv* is very rarely used in German mathematical discourse in comparison with the *Vorgangspassiv*.

If this is the case we would have to assume that pseudo-reflexive constructions are **too impersonal**, since they do not **hide** but **remove** acting participants from the discourse perspective.

We could expect that pseudo-reflexives may be used in statements of mathematical facts, i.e. in fully impersonal parts of mathematical discourse. This, however, is impossible since the sets of predicates used in theorem-like statements and in pseudo-reflexive constructions are disjoint. Expressions of the first type, i.e. theorem-like statements, cannot be related to humans (thus they contain relational and existential predicates with the feature <OTHER> as semantic specification on their PF-slots). Pseudo-reflexives, on the other hand, are possible only for predicates prototypically associated with humans. Therefore, this type of 'impersonal' construction cannot be used in theorems.

There is yet another reason why pseudo-reflexives are not used in mathematical discourse. As was illustrated in (2)-(5), this syntactic construction is practically always used with some adverb of manner characterising certain aspects of the process or action described by the predicate (cf. *nur mühsam* in (2b), *gut* in (3), *dobrze* in (4) and (5)). The presence of this adverbial phrase is a necessary condition for using the pseudo-reflexive form. Scientific discourse in general avoids explicit expressions of quality judgements. Adverbs of manner are quite rare in mathematical texts, and since they condition the use of pseudo-reflexives, we may well expect that these will not be frequently used either.

5.1.4 Other Consequences of Impersonal Rhetoric

So far we have discussed mainly syntactic means of indirect reference, that is, rearrangements of the predicate arguments which result from the 1st argument demotion down the hierarchy of grammatical relations. In this subsection we discuss yet another method of indirect reference, which may be labelled *personification* of certain inanimate objects. This phenomenon might be seen as a most natural consequence of impersonal rhetoric. However, it is common in non-technical and non-scientific communication as well and could be simply considered as a result of language economy. We concentrate on the syntactic description of the personification in terms of the PF model. Examples below illustrate this phenomenon:

(7) *Die vorliegende Arbeit liefert* einen axiomatischen Aufbau der minkowskischen Geometrie...
'this study gives an axiomatic structure of Minkowski geometry...'

(8) *Die nebenstehende Tabelle zeigt* die Eigenschaften des zur jeweiligen Geometrie gehörigen "Skalarprodukts"...
'the table shows the properties of the 'scalar product' which belongs to the given geometry...'

(9) *Die Sätze* 1.47 (für eigentliches G) und 4.2 *besagen* zusammen...
'theorems 1.47 (for proper G) and 4.2 state together...'

(10) *Die Beweisbarkeit* des euklidischen Parallelenaxioms ...
zeigt insbesondere, daß...
'the fact that the Euclid's axiom of parallel lines can be proved ... shows in particular, that...'

(A-12)

In the examples, above predicates *liefern* ('to deliver'), *zeigen* ('to show'/'to demonstrate'), *besagen* ('to state') have the subject position filled, not by expressions referring to the 1st participants, but to some sorts of *peripheral participants* in the event or its *circumstances*. Therefore, the 1st participant is not demoted but simply replaced by an element which does not belong to the relevant PF. Consequently, the syntactic shape of the clause does not change. Although personification of inanimate objects (i.e. linking these objects with predicates prototypically associated with human activities) is an impersonal option readily available in German (both in scientific and in non-scientific discourse), it is stylistically marked as 'figurative' or 'metaphorical', and as such not frequently used. Its use is largely dependent on the individual speaker's preferences. In our corpus, personification was used almost exclusively in text A-12.

In mathematical discourse, shifting of the acting participants in the background is accompanied by foregrounding of the objects related to the discourse topic. The major part of any mathematical discourse consists of statements of mathematical facts, and as such it is *a-personal*, *a-temporal* and *a-spatial*. Since in this thesis we are interested in the reference to human discourse participants only, we have left all theorem-like elements of mathematical discourse out of consideration. At the end of this section, however, we briefly mention one linguistic phenomenon characteristic of these sections of mathematical texts.

Since in theorems no reference to humans is possible, only *a-personal* predicates are licensed. This is because, as noted by, e.g. Weisgerber [1963], due to the properties of personal verbs, Indo-European languages do not allow for a fully agentless presentation (we commented on Weisgerber's statement in more detail in Subsection 1.2.3). Verbs used in German for theorems comply with the a-personal requirement. Their PFs have either no prototypical specification on the 1st argument slot (i.e. they have the feature <OTHER>), or they specifically require the features <+ Inanimate> or even <+ Abstract>. Examples of the first type of predicates are all sorts of relational verbs (equative,

attributive, locative etc.), existential predicate *es gibt* ('there is'), verbs such as *heißen* ('to be called'), *besitzen* ('to possess'), etc. To the second class belong verbs such as *gelten* ('to satisfy') or *bestehen* ('to consist') etc. For these two semantic classes of predicates no prototypical personal interpretation is possible.

The following last section of this thesis presents conclusions from the research on reference in German mathematical discourse and attempts to answer the question: Is scientific discourse really impersonal?

5.2 Conclusions

5.2.1 Indirect Reference in Mathematical Discourse

The research presented in this thesis originated from an interest in the syntax and semantics of impersonal constructions in German. We decided to investigate these constructions as used in scientific texts, where they are particularly frequent. In the course of analysis of the data from written and spoken mathematical discourse it became apparent that the problem may be viewed from at least two different angles, that is either from a purely formal perspective or from a discourse perspective.

Independently of which of these approaches is adopted, the common point of departure for the analysis is the fact that *impersonal* constructions in German (and in many other Indo-European languages) are allowed only for *personal* verbs, i.e. for verbs prototypically associated with human activities. Thus, in German, clauses with the subject *man*, or with passive and pseudo-reflexive constructions, are possible exclusively for verbs which could otherwise turn up with personal subjects referring to humans. Consequently, this prototypical semantic link with human agents can be inferred even if no explicit reference to the acting participant is made.

If the formal point of view is taken, impersonal constructions may be assigned a personal interpretation because of the predicate semantics. However, since the syntactic structures are analysed in isolation, that is, without any co-text and out of situational context, the semantic interpretation may only be *indefinite-personal*. As was pointed out by Strawson [1959] and as is generally assumed among philosophers, definite reference cannot be achieved by means of indefinite expressions. This assumption must be revised when impersonal constructions are analysed in the *restricted context* in which they were originally used.

In naturally occurring communication (as opposed to contrived examples), impersonal constructions do not turn up in isolation but are used as an element of discourse and as such must be analysed in terms of discourse. Human communication always takes place in a more or less well-defined situation. Scientific exchange of thoughts is an instance of communication in a fairly *restricted context*. If the language use in mathematics is chosen as the object of investigation, additional

factors, relating to the deductive character of this science, facilitate the reference interpretation (cf. Section 2.2). If pragmatic factors are taken into account, along with the specific *impersonal rhetoric of mathematics*, most of the constructions with impersonal syntax used in mathematical discourse prove not to be impersonal. They are interpreted not just as personal, but as *definite-personal*. That is, the speaker is able to use them distinctively to refer to different participants involved in the communication.

In the restricted context of scientific communication the interpretation of reference is supported not only by the personal semantics of the predicate but also by the context-specific link between arguments of the predicate and context-specific *discourse roles*. And since they are in turn constantly associated with particular referents (i.e. with specific participants in the communication), definite reference to those participants may easily be achieved in an *indirect* way, that is by means of impersonal constructions. Thus, restricted context sets different parameters for the reference interpretation than those of the sentence grammar. These context-specific parameters cannot be easily formalised as a set of rules, which is a common problem in the description of any discourse phenomena. Philosophical or formal approaches, on the other hand, offer complete models which are interesting as theories of reference but often fail to fit real language data.

The approach adopted in this thesis was an attempt to describe the phenomenon of indirect reference in the language of mathematics at discourse level, that is, taking pragmatic factors into account. Assuming that pragmatic factors determine syntactic choices, we have concentrated on the syntactic and semantic aspects of indirectly referential expressions.

We assumed that the verb is the nucleus of a sentence. Semantics of the predicate, i.e. its "logico-semantic valency" (cf. Helbig [1982]) determines the number and type of arguments that it may be associated with in the language use. Taking this approach, we naturally followed many lines of the research on valency and case grammar, since these theories have the concept of verb centrality in common. Description of reference phenomena requires us to take into account three aspects of linguistic analysis:

- the semantic aspect, i.e. participant roles associated with predicate arguments;
- the syntactic aspect, i.e. grammatical relations assigned to the predicate arguments;
- the pragmatic aspect, i.e. pragmatic function of the predicate arguments.

Pragmatic factors cannot be easily accommodated in a linguistic model but they decide which of the options available in syntax for the description of a certain state of affairs will be chosen. Thus, in the predicate frame model presented in this thesis, the syntactic component is a set of options symbolised by the conditional 'If-Then' facets associated with PF argument slots (cf. Section 3.2 for the notion of syntactic *facets*). Syntactic choices depend on the pragmatic function assignment. Semantic interpretation is read from the declarative knowledge about predicate arguments stored on the PF-slots. No attempt was made to give the model a complete formal shape or to combine it with any of the current theories of grammar. However, theoretical concepts employed in this thesis, such as e.g. *prototypical participants* or context-specific *discourse roles* linked with predicate arguments, may be effectively used in other frameworks. We believe we have shown that, with the mechanism of reference interpretation described in this thesis, impersonal constructions used in German mathematical discourse may be assigned definite-personal readings.

5.2.2 **Applications and Further Lines of Research**

The model presented in this thesis was developed to handle specific cases of a non-isomorphic mapping between syntax and semantics. As such, it seems to be suitable for describing instances of a discrepant relation between these two levels of representation other than syntactically impersonal constructions. We believe that phenomena such as, e.g. reflexivisation, could be further investigated in terms of the PF model. This model allows for a clear distinction between reflexive elements with or without equivalents in the semantic representation and, consequently, with or without grammatical functions. We would like to apply the concept of predicate frame to impersonal and reflexive constructions in Slavic languages to see how the distinction between clauses without an overt subject (i.e. clauses with deictic pronouns omitted due to the fully specified personal form of the predicate) and impersonal constructions could be made. Another problem which is worth

looking at is the question of constraints on extending the PF model to other parts of speech (i.e. to deverbal nouns and adjectives).
Another interesting area of investigation which could not be further explored in this thesis is the problem of 'competition' between prototypical semantic feature specification on the PF argument slots and features added by the lexical items filling a given slot. In this context, problems such as metaphorical or allusive use of language could be investigated. *Allusion* is commonly defined as 'indirect reference'. It could be interesting to compare it with indirect reference in scientific discourse to see whether it also requires a *restricted context* to be adequately interpreted. The problem of pragmatic function assignment in restricted contexts should be further investigated, with particular emphasis on the way in which pragmatic functions influence syntactic choices.

The analysis of indirect reference presented here was carried out on data from German mathematical discourse and we should mention in these closing remarks at least one aspect in which this research is relevant for LSP teaching. The results confirm that scientific discourse employs specific means, not available in everyday communication, in order to achieve its specific goals. The results also show that certain linguistic means, used in both contexts, have different functions in scientific and non-scientific communication. Therefore, in teaching languages for special purposes, it is essential to teach linguistic forms as related to their *context-specific functions* and not merely as phenomena of grammar. So, e.g. it would be misleading to say that the German *man* is used to express reference to some indefinite individual or group of individuals, since this is practically never the case in mathematical discourse. Here, *man* can be used for self-reference, reference to the definite audience (when with *Konjunktiv* I or with modal verbs) or for expression of general truths. Linguistic analysis of LSP and teaching *language for specific purposes* require not only the knowledge of the *language* itself, but also understanding of the *specific purpose* the language is used for.

We believe that the methods developed and the results presented in this research give some guidance for the further investigation of the relations between syntax and semantics when language is used in restricted context. We also hope that the observations about the mechanism of reference in German mathematical discourse could be directly applied to LSP theory.

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APPENDIX 1

Texts used for analysis:

Corpus A: Written discourse

A-1 Kleine Büning, H. (1983) Durch syntaktische Rekursion definierte Klassen, in: Zeitschrift für mathematische Logik und Grundlagen der Mathematik **29**, pp. 169-175;

A-2 Fritsch, R. (1985) Zur Kantenwinkelsumme der regulären Pyramiden, in: Elemente der Mathematik **40**, pp. 68-75;

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A-4 Kuhlmann, N. (1969) Niveaumengenräume holomorpher Abbildungen und nullte Bildgarben, in: Manuscripta Mathematica **1**, pp. 147-189;

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A-6 Landau, E. (1923) Über die Gitterpunkte in einem Kreise, in: Landau, E. (1962) Ausgewählte Abhandlungen zur Gitterpunktlehre, VEB Deutscher Verlag der Wissenschaften, Berlin, pp. 85-92;

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A-8 Tornier, E. (1940) Neuer Beweis der Äquivalenz der Meßtheorien mit verschiedenen Verknüpfungsoperationen, in: Deutsche Mathematik, pp. 212-216;

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A-10 Schiffels, G. & Stenzel, M. (1984) Einbettung lokal-beschränkter topologischer Ringe in Quotientenringe, in: Results in Mathematics 7, pp. 234-248;

A-11 Matzat, H. (1985) Realisierung endlicher Gruppen als Galoisgruppen, in: Manuscripta Mathematica **51**, pp. 253-265;

A-12 Wolff, H. (1967) Minkowskische und absolute Geometrie I, II, in: Mathematische Annalen **171**, pp. 144-164, 165-193;

Corpus B: Spoken discourse

B-1	Prof. Wrobel	-	Partielle Differentialgleichungen II
B-2	Doz. Johnsen	-	Geschichte der Galoistheorie
B-3	Dr. Kerby	-	Algebra II
B-4	Prof. Kosmol	-	Von der Variationsrechnung zur Steuerungtheorie
B-5	Dr. Schaller	-	Konvexe Mengen
B-6	Prof. Wolff	-	Absolute Geometrie II
B-7	Prof. Günzler	-	Verallgemeinerte Funktionen
B-8	Dr. Schnabel	-	Euklidische Geometrie

APPENDIX 2

Translation of the discourse examples in Chapters 4 and 5.

Example 4.1 (from page 100)

...now we want to say we have a dissipative operator/well/that could be our last part for today/definition/t of x dt by x linear t is called dissipative iff for every x out of dt there is an x prime out of f of.../i.e. a functional/such that the real part of x prime applied to dx/that this is less or equal zero/one would never believe that one can use it/that is why I'll give you the theorem at once/we prove it next time but I do not want to let you go away for the weekend with this definition because, as it was said, one does not believe that one can use it for anything/.../this is such a uniform confinement of this mapping down there/this means then, that if this thing here was surjective/it is injective/then one has exactly one estimation as one needs it for Hiller-Phillips/one has it simply from the inverse operator from there/.../this means then/if one can somehow make sure that t is closed and that it is somehow surjektive then one has already the condition/and it turns out that although this condition here looks crazy, one can calculate it relatively simply/.../one has to take an x out of dt and then one has to find such an x prime out of fx, while one does not know how difficult it is to define fx/but one only has to look at it/one does not have to calculate any norm/nothing/one lets a functional down onto tx/ and now if one wanted to calculate the norm of, say, tx or so/then one would have to take all functionals/... or so...

(B-1)

Example 4.2 (from page 101)

C) Rational homotopy of S^1-fibres. In the following we are looking for a manifold with $H^*(B,Q) \simeq H^*$ and for a S^1-fibre $p:E \downarrow B$, such that ϵ and m are rational homotopy equivalent manifolds. B shall be first constructed as a rational space and we use here Sullivan's rational homotopy theory.

...

Theorem 2.8. Let P:E↓B be a S^1-fibre. Then there is... One obtains theorem 2.8 easily from the Grivel's theorem. The last equation in theorem 2.8 is to be understood as a "differential equation", which one has to solve grade by grade:... Then,... must be satisfied. The right side is determined because $d_E(X)$ is resolvable.

D) Construction of free S^1-operations up to the rational homotopy equivalence. If one can state τ as in theorem 2.8, then the short exact sequence..., where p denotes the augmentation, induces long exact sequence, similar to the Gysin sequence. Then one would like to choose τ - and consequently also d_B - in such a way that the above sequence can be bound by a ladder of isomorphisms...

(A-7)

Example 4.3 (from page 115)

...the problem that one has first is to see that this set is not empty/so firstly r x is not empty/well if x is equal to zero one does not have great difficulties/does he?/only if x is not equal to zero/so that this thing is not empty/well then we simply apply the Hahn-Banach/then we simply do it this way/for a given x we define us statements/well/how shall we do that?/how shall we denote that?/let φ of x be the norm... and this because we define φ as a mapping from the product of x.../and we continue this mapping linearly/and we want to make φ to be a linear mapping onto the product of x with values in the field/we do it simply fairly brutal/we continue linearly...

(B-1)

Example 4.4 (from page 126)

so the set a has inner points and the intersection of the two sets is empty/according to the separation theorem which we have just written down/this is the separation theorem by Eidelheit/one can separate the two sets/separate with a hyper-plane/well, by Eidelheit/where are we?/here/theorem by Fenchel/this is then the statement/yes/here/we have been so far/the following is satisfied/X_1 applied to y .../ or y applied to.../this is what I wanted to write/y applied to x.../.../so if we had.../we can estimate $\beta = 0$ and then

here stands.../we shall consider now this here as a contradiction/.../now we want to say, this is a contradiction/ and we want to consider this together with.../.../we have already considered this/.../why does it not work now?/we have points out of the finite domain now/this is perhaps very brief/this theorem here../but one would possibly have to consider also.../(one would have) to derive this theorem precisely/although geometrically it is very easy...

(B-4)

Example 4.5 (from page 127)

so when these relations are satisfied then, we say, then these problems are weakly dual and dual/.../one denotes this as dual or strongly dual/.../this is called dual and then one distinguishes when the two problems are soluble, then one denotes it also as strong/this, however, is of secondary importance/this distinction/for us now the most important thing is when these two/that these two (have) the same value.../this means that when we have solved one problem and found the value then we have also solved the dual problem/we have at least found the value of the dual problem/.../those who have once done anything connected with the linear programming or something like that/then you will realize that exactly because one has the dual problem/.../generally for the first time one could define something like simplex algorithms/thus one always needs, when one calculates...,a significance criterium/one would like to know whether one is gone far enough in calculations so that one can finish them/that one has already reached the required accuracy/and this is a very important question...

(B-4)

Example 4.6 (from page 130)

We shall now try to prove for manifolds a result analogous to 3.4. ...

It follows

Theorem 3.5 1) X' is a Poincare-complex;

2) X'/Z_r can be treated as a simple Poincare-complex;

3) the Spivak's normal bundle $\bar{\upsilon}: X'/Z_r \to GB$
shifts to B Cat.

We fix a lifting and obtain... .

Thus, we only need to find out when... For this we consider an explicit rational equivalence... .

If we use the natural isomorphism (in a simple case we need here condition P4)... and the property..., then obviously follows that... . Now we obtain... .

(A-7)

Example 4.7 (from page 130)

If $\epsilon : k[e] \to K$ denotes an augmentation homomorphism ($\epsilon(e) = 0$), then, using the isomorphism given before, the Gysin sequence may be represented in the following way:... .

Now the multiplicative structure of the cohomology rings must be considered. In the following way one obtains... Then one defines...

Proof of lemma 2.5 . First we construct a suitable subalgebra... by specifying the generators and we define a bilinear form...

(a) $m = 2l$. One shall choose a maximal ϕ_m isotropic subspace K^l... To prove (a) one can substitute:...

(A-7)

Example 4.8 (from page 131)

1. Introduction

The syntactically restricted recursion was introduced in [1], to describe ... certain classes of Turing machines with time limit. In the following investigations, e.g. [3,4], this operation proved to be well suited for description of the internal complexity of function classes. So, e.g. the classical problem PTIME = PTAPE may be formulated in the recursion theory as a question of the equal value of... . Going out from the standard syntactically restricted recursion we shall introduce new operations by reducing the number of the steps of recursion.

2. Definitions

First, we want to set the abbreviations for some functions...

Now we introduce the syntactically restricted recursion of the m-th level.

(A-1)

Example 4.9 (from page 134)

I want to present here shortly the proof for $r = 1$ to demonstrate the application of conditions (G), (A) and (R)... According to (R), K/k is a rational functional field, so that now the proposition of the embedding theorem follows, in the case of $r = 1$, from the Hilbert's theorem of irreducibility.

(A-11)

Example 4.10 (from page 134)

We shall now consider classes H_m^*.

...

Now, we want to give an additional characteristic for classes $H_m (m \geqslant 2)$.

(A-1)

Example 4.11 (from page 134)

Since the main result from [4] goes into the proof of theorem 2, it seems useful to add some remarks about this here. The question here concerns the equivalence of the (normal) complex space in the sense of Behnke, Stein on the one hand and in the sense of Cartan, Serre on the other hand.

(A-4)

Example 4.12 (from page 134)

...so this is as it was said/at least I hope so/good to read/.../these are the most important theorems about conjugated functions... /connection between ... shall be characterised now and here/later I wanted to include this theorem in the text, therefore I have the numbering/so the theorem begins here/here.../those who have the script do not need to take notes now here/as it was said I do not want to assume now that you.../already...the script/have read it/so we now use the script really only as a complement/and so I ask you to.../only few pages which now.../which now belong to this lecture/which you should have a look at and now/also now/.../so now they are also meant as a complement...

(B-4)

Example 4.13 (from page 135)

...well then we have done it/haven't we?/so/now we want to say we have an operator/a dissipative one/well this may be our last part for today...

(B-1)

Example 4.14 (from page 135)

...now we would like to see the period six two/six two/well, this is a different period/this he (i.e. Gauss - M.S.) also does.../so, how can one do this now?/...now we could obviously/now is/lambda is equal to two/this goes now here with two plus... two times.../how shall we do this?/.../well, here at the back stands simply.../but the question is/the one that we just have/how do we obtain all other periods here?/here, he took the one.../here he took the two/which lambas shall we take to obtain all periods?/.../this here is an old trick from the general number theory/and for this, one has to calculate the product of two periods/and this was for a long time, I believe, very difficult for Gauss/and is also up to the present not so simple/but he does this with his remarkable notation/here in the article three hundred forty five/very clearly/here one calculates the product of two periods/well/we can do the rest on Monday...

(B-2)

Example 4.15 (from page 142)

...and one takes a generator and/so this/this is clear/and the second case/let k be infinite/then one has to argue as follows/well we still need the field up there/so we do the following/so we presuppose.../.../now one has to consider the following...

(B-3)

Example 4.16 (from page 144)

Let V(n) be the number of decompositions of n into two squares

(formula).

Mr. Cramér proved for each $\epsilon > 0$

(formula)

where

(formula)

I shall simplify the Cramer's method and lead it to the proof of a new theorem

(formula).

(A-6)

Example 4.17 (from page 145)

With the help of condition 1, Belyi could show in [2] among others, that all classical simple groups ... are Galois groups of the regular extensions of fields over $Q^{ab}(t)$. ...The extensions of fields N/k(t) ... show symmetries in the branching structure. I use this for a sharper criterium of being rational, here only for s = 3 because of the simpler form. For this I write... and define...

Then, by the operation of the generating elements of S_3 , one obtains an operation of the elements... (see [11], condition 3.5 or [12] condition 6.3). If one denotes the number of paths under these operations as..., then again there are...

With conclusion 2b) one can show, for example, that all primitive not soluble groups of permutations of grade d ≤ 15 may be represented as Galois groups over Q(t). At the end of the first section I shall present two more examples with s = 4.

(A-11)

Example 4.18 (from page 147)

...now when this is less than or equal to λ then we simply substitute this/so this is somehow quite simple/so now when this...than you can substitute it/...with that we are a step further on.../so now we have to consider a group of contractions/now the problem which initially occurs is/there could stand an m here/.../and we do not know anything about it in the moment/we can, however, eliminate this.../what we still have to note is that if instead of a semi-group of contractions we have a general one.../then we simply drop the Ω t .../and what remains is.../ are restricted semi-groups.../and this problem, we will get rid of that too but not right away...

(B-2)

Example 4.19 (from page 147)

...and, no doubt, what I present here and now is obviously not the beginning of the story but the end of it/isn't it?/obviously, this was first done for Hilbert spaces/and then the question was obviously how one finds an appropriate generalisation for Banach/spaces and with conditions which I write down, to begin with, you probably first think about Hilbert space/but I formulate it immediately also for Banach space/and this goes now/...for the time being it is very abstract/and I want you to swallow it first simply as it is...

(B-2)

Example 4.20 (from page 150)

1. Please do not read the following foreword for the expert!...
3. Please forget everything that you learned at school because you didn't learn it.

(A-5)

Example 4.21 (from page 150)

Excuse me if I call you *Du*; this happens not only because one is used to addressing the reader with *lies* ('read') and *siehe* ('see') but because this book is written partly in usum delphinarum.

(A-5)

Example 4.22 (from page 150)

But if the material seems so easy to any colleague with a different approach that he uses it in his introductory lectures, I would have reached a goal which I dare not hope for in the wider sphere.

(A-5)

Example 5.1 (from page 161)

in the last session we had defined what one understands by an algebraic extension and by a transcendental extension/and then we have theorem twenty five...

(B-3)

Example 5.2 (from page 161)

...and if we want to prove today the theorem.../well last time we occupied ourselves with the separation properties/thus we separated convex sets which have an empty intersection, with hyperplanes/today we also want to occupy ourselves first briefly with hyperplanes and then we shall consider...

(B-5)

Example 5.3 (from page 161)

...well now we wanted to consider this Gauss's theory of periods/and this...tells us the following/we have an odd prime number d to the power p/odd/and we consider that p is the divisible polynomial/I denote this as usual π t of p/.../and we want to solve this thing algebraically...

(B-2)

Example 5.4 (from page 162)

1. Introduction

The question, whether each closed manifold permits a non-trivial operation of a compact Lie group G, was answered negatively by many authors... . We show here among others, that...

(A-7)

Example 5.5 (from page 162)

1. Introduction

Let X be a random variable and let f(t) be its characteristic function... In this note we characterise the set of null values of f(t) in the following three cases:...

(A-9)

Example 5.6 (from page 163)

Introduction

In Part I of this paper we considered a generalisation of the Schmidt-Banach's system of axioms of the absolute geometry which is also satisfied by the Minkowski geometry (system of axioms A). In the following, the part of the system of axioms A, which goes beyond the Schmidt-Banach system of axioms, is investigated (i.e. system of axioms A').

(A-12)

Example 5.7 (from page 163)

On the 9th October 1796, C.F. Gauss notes in his diary the theorem that for an odd prime number p, each non-trivial integer linear combination of the primitive p-th...roots is not equal to zero. This is obviously equivalent to... . If we generally denote the Q-subspace of C generated by the roots of a polynomial f(t) as..., then we can express the Gauss's theorem in the following form:...

(A-3)

Example 5.8 (from page 169)

Since the 'Disquisitiones arithmetica' are, due to their form, a magnificent classic work, the study of them in the original can never be advised too strongly. Those, however, who are initially interested only in learning the content, should also be grateful, if they are enabled to concentrate their attention on the content itself by the removal of the external difficulties. Therefore one may hope that the German version presented here will be welcomed by many readers.

Example 5.9 (from page 169)

In order to become acquainted with this work I had studied it to such an extent, that I translated it into German and tried to explain by words and calculus all those places which for me were not clear by themselves.

...

I believed that this preface was indispensible to make sure that this work is seen from the right perspective; Finally I express the wish that this first part may find a favourable reception.

Example 5.10 (from page 170)

We have generally an identical equation... . From this new solution one can derive in the same way a third one etc. One easily finds out that when the first solution is in real numbers, the third one is also like this. It should also be noted, that when a, b, c do not have any factor in common, the same is true about a', b', c'...

Example 5.11 (from page 170)

Since in the following, powers of the root r are considered, whose exponents are again powers, expressions of this type, however, cannot be easily represented in print, thus, to facilitate the printing, we shall use below the following abbreviations.

Example 5.12 (from page 171)

The aim of the following investigations, which to mention briefly will not be superfluous...

Example 5.13 (from page 171)

In liquids, as we shall see later, where the movement of bodies in them is discussed, the resistances by the same speed are proportional to the density of liquids.

Example 5.14 (from page 171)

Among formulae by which one could easily multiply those given by myself in the Fundam. nov., it seems to me that the following one,...,has a remarkable nature.